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THE GYROSCOPE AND ITS APPLICATIONS

REMARKABLE EXHIBITION OF ITS GREAT POWER—USE IN STEADYING SHIPS, MONORAIL LOCOMOTION, AERIAL CRAFT AND AS A MARINER'S COMPASS

THE 670th meeting of the Society of Arts was addressed by Mr. E. A. Sperry of New York, who described the practical uses of the gyroscope and some new applications of gyroscopic principles to which he has given a great deal of study. He passed the summer of 1909 in Europe investigating various applications of the gyroscope including Doctor Schlick's method of ship control and the Brennan monorail railroad. Besides many lantern slides, the lecturer demonstrated the principles of the gyroscope by means of ingenious operating apparatus. It is unfortunate that the press of other matter does not permit us to print Mr. Sperry's lecture in full, and, we therefore may not be able to give as complete an explanation of precession as is necessary to make this phenomenon perfectly clear.

Mr. Sperry said that there was in the early history of our navy a torpedo known as the Howell torpedo which depended for its action upon the rapid rotation of the fly-wheel. The torpedo was a cigar-shaped device and amidships was a steel fly-wheel some 16 inches in diameter which rotated up to about 16,000 revolutions per minute. This rotation was so great that the clearance of 1-64 of an inch around the periphery of the fly-wheel was taken up by the expansion of the wheel due to centrifugal stress and was utilized as an automatic brake. The fly-wheel was spun up by a Dow steam turbine which was the forerunner of the steam turbine of the present day. Mr. Nixon, late of the navy, had charge of the marksmanship tests with the Howell torpedo. At the first trial they had some difficulty in starting the machinery, but after the required velocity of the fly-wheel had been fully reached, it was found that the warship on which the torpedo was located, and which was anchored in the bay, had been turned by the tide and the torpedo which had been pointed toward the target, was now pointed in an entirely different direction. Several of the members of the crew were called to point the torpedo over toward the target, but they found it impossible to make it change its direction. A large gang of men was pressed into service and in response to the great force employed, the torpedo began to slowly change its direction with relation to the ship. Upon sighting the torpedo, however, it was discovered that it was pointing as far from the target as ever, and on examination it was found that the torpedo with its gyroscope wheel had absolutely refused to turn. The crew had moved the ship around under the torpedo. This

was one of the first occasions when the tremendous power of the gyroscope manifested itself.

Referring to Fig. 1, Mr. Sperry then described the gyroscope. There is a spinning mass A suspended in a universal joint made of two rings C and D pivoted together at EE and supported on the pivots GG by the standard F. The ring C is called the precessional ring and the ring D is called the base ring. In this particular cut there is a brake wheel I attached to the precessional ring in such a way that it may be locked to the base ring D. Please understand that in this case the brake is loosened, so that the two rings are free to move with relation to each other about the pivots EE. When a force is impressed on the ring D a very peculiar thing happens. The instant such a force is applied, the inner ring C containing the spinning disk instantly swings vigorously upon the pivots EE and the precessional ring C is tilted with reference to the base ring D. If we spin the wheel A in an opposite direction and impress a similar force on the ring D, the ring C will be tilted in a direction opposite to that which it before assumed. This reaction is known as precession and is the same phenomenon as is observed in a spinning top when it leans away from the perpendicular as it loses its energy of rotation. The tendency to fall is like the impressed force on the ring D which gives the top a precessional movement precisely the same as the poles of the earth have a precessional movement in space. The precessional movement in this case is that described by the head of the top as it swings about its orbit.

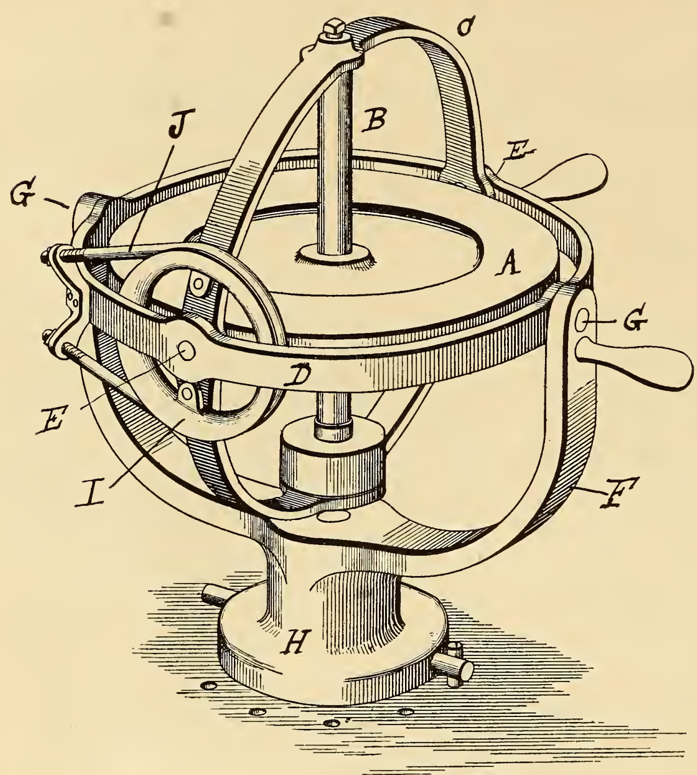


Fig. 1 Gyroscope

The lecturer then exhibited a piece of apparatus consisting of a stool supported on a pivot so that it could freely revolve, and attached to the platform on which this stool was secured was a bicycle wheel, but instead of having a rubber tire, the rim of the wheel held a solid ring of lead of great weight. The bicycle fork had a lever attached to it so that the operator sitting on the stool could turn the fork through 180 degrees. Mr. Sperry's son then occupied the stool and holding the fork, so that the plane of the wheel was vertical, the speaker revolved it rapidly making it in effect a gyroscope. As long as it remained revolving in this plane, there was no movement of the stool, but the instant the operator rotated the fork so that the revolving wheel occupied a new plane, the stool and

Fig. 2

operator were violently moved about the supporting pivot through a portion of an arc of a circle. Upon repeating the experiment, the wheel was revolved in another direction and, on changing the angle of the wheel's rotation, the operator and stool were revolved in a direction opposite to that which took place in the first instance. This demonstration although remarkable in its simplicity was of the most convincing character. The apparatus is shown in Figures 2, 3 and 4; Fig. 2 showing the wheel revolving in a vertical plane and the other two figures showing what took place when the plane of revolution was inclined. This revolution of the stool about the pivot is another demonstration of the phenomenon of precession.

Following this exhibition the lecturer then proceeded to explain the theory of precession by means of diagrams and a home-made apparatus in which as he said he manufactured precession to order. Unfortunately the apparatus cannot be as clearly shown as would be necessary to make the explanation plain.

Mr. Sperry stated that some time ago he had enunciated a principle of the gyroscope which he has since been able to demonstrate, to the effect that any amount of force inpressed upon the axis of the gyroscopic wheel could be taken off without diminution at right angles to the direction of the impressed force, or that the amount of stress impressed in one plane can be fully recovered in another plane. This principle he has applied to a novel gyroscope coupling which has attracted much attention.

The speaker said that one of the most extensive uses of the gyroscope was in the automatic steering gear of the Whitehead torpedo. This gear is used for the purpose of guiding the torpedo laterally and holding it to an absolutely straight course. The small gyroscope employed had a secondary ring which may precess and which is used to operate valves and through the secondary motor direct the rudders. Its use for this purpose was originated by Obrey, an Austrian naval officer. Our own Lovitt, engineer of the E. W. Bliss Company of New York, and inventor of the Bliss-Lovitt torpedo, has greatly improved the gyro-gear of the torpedo. as he has greatly improved the torpedo itself.

Mr. Sperry then took up the experi-

Fig. 3

ments that have been made in steadying ships which Froude tried to accomplish by the use of water chambers placed athwartships. When the ship rolled, the water would flow from side to side and to some extent dampen the vibration. The

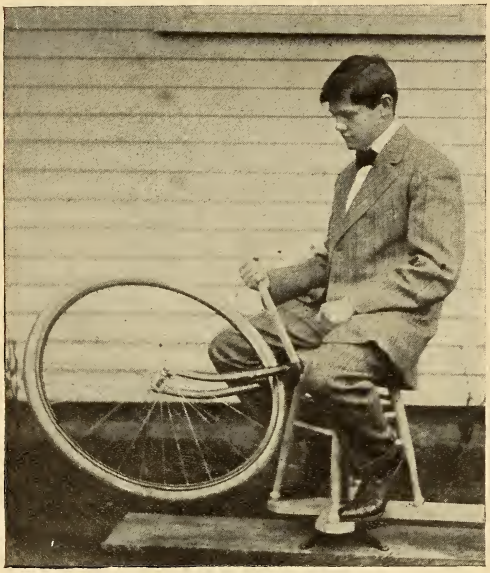
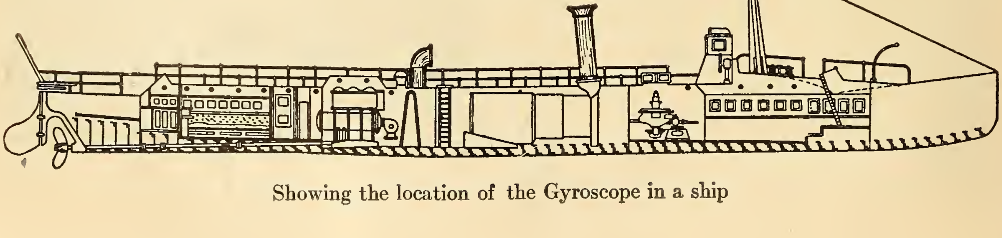


Fig. 4

bilge keels that have been introduced to prevent rolling depend for their effect upon the movement of the ship through the water. Extra power is required to drag them in calm water as well as in rough weather when they are needed. Doctor Frahm, whom the speaker met in Germany, has succeeded in overcoming the intolerable noise made by the rush of water through the water chambers in Froude's plan, by using a connecting siphon. This, however, must be so arranged that it operates synchronously with the boat's period of swing. In a rough sea, the period often varies from seven to seventeen seconds. Sir John Thornicroft tried to overcome the last difficulty by placing a great moving weight on a vertical axis in such a way that it could be swung either to one side or the other, thus changing the center of gravity of the ship. Hydraulic apparatus was provided for swinging this weight from side to side. In this way he succeeded in reducing the roll considerably. Sir William White states that it reduced a roll of eighteen degrees to nine degrees. The principal trouble was that it required an immense weight to produce the desired result; for by this gravitational method a pound of weight is able to do only a pound of work, and the weight of the machinery required to properly steady ships would be prohibitive.

During the summer the lecturer spent considerable time with Doctor Schlick in Hamburg, Germany. It is to Doctor Schlick's genius that we largely owe the vibrationless reciprocating marine engine. He has gone further in the installation of large gyroscopes for steadying ships than any other man and in his successful experiments he has been assisted generously by his friends of the Hamburg-American Line. Doctor Schlick told the speaker that his attention was first called to the use of the gyroscope for steadying ships by observing the behavior of a side wheel steamer. He noticed that whenever one of these boats rolled, her bow would be thrown around in a direction contrary to that which is observed when the boat is said to "yaw," that is, if she rolled to starboard, her prow would go around to starboard, which is, of course, the phe-



Showing the location of the Gyroscope in a ship

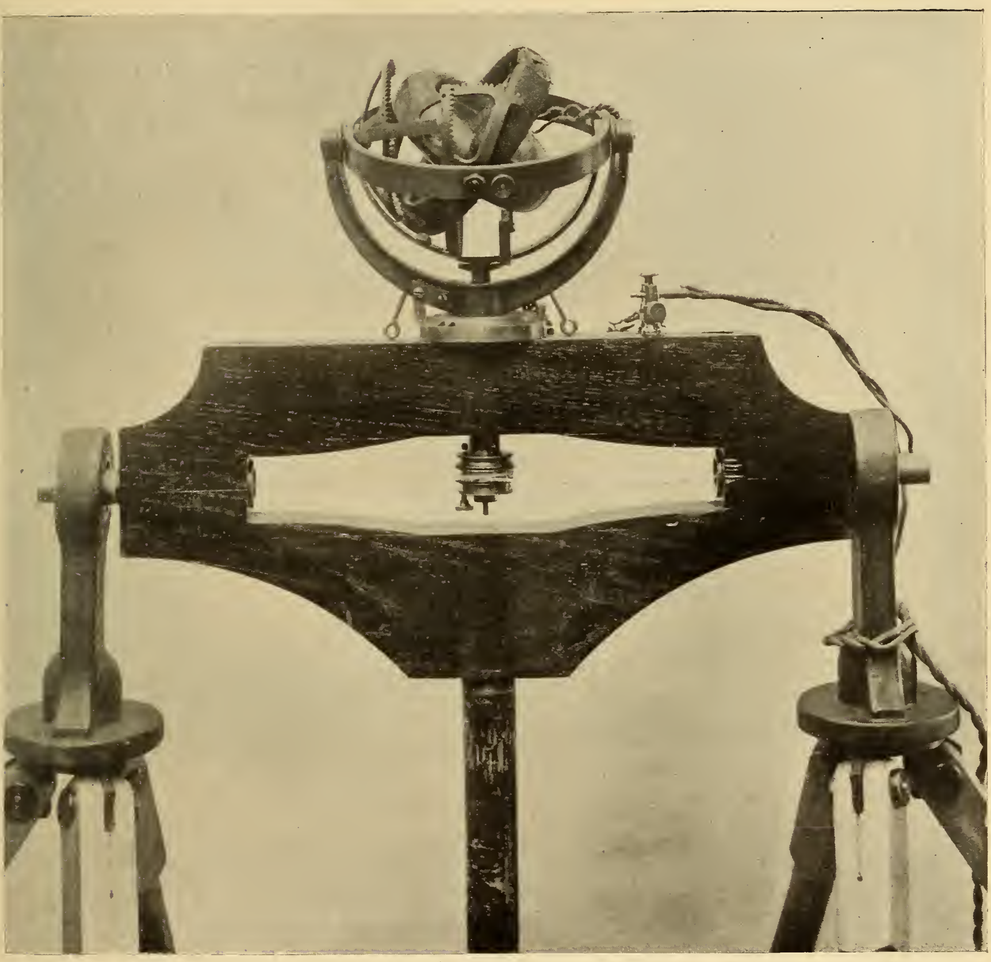


Fig. 5. Electrically actuated Gyroscope on a Pendulum

nomenon of precession. Mr. Sperry corroborated these observations by making a special trip for that purpose under weather conditions that made Doctor Schlick's deductions obvious.

When after a long period of research Doctor Schlick satisfied himself of the effect that could be produced by the gyroscope in a ship, he wrote Sir William White asking "If I can hold the ship from rolling, will her decks be dry; will she ship seas?" to which the great naval architect replied,—"If a ship can be held from rolling, she will not ship seas and her decks will remain dry." Since that time he has installed a gyroscope on the Hamburg-American steamship, *Silvania*, loaned for the purpose and on which Mr. Sperry was an invited guest. In rough seas the ship was prevented from rolling by the gyroscope and as Sir William White predicted, the decks remained dry.

The gyroscope is probably the only device which can transfer energy around a corner, so to speak. By means of this device a fulcrum can be maintained in space effective for the heaviest kind of mechanical duty, and every rotating pound in the mass of the gyroscope can be made to do much greater work than it could do under the influence of gravity alone.

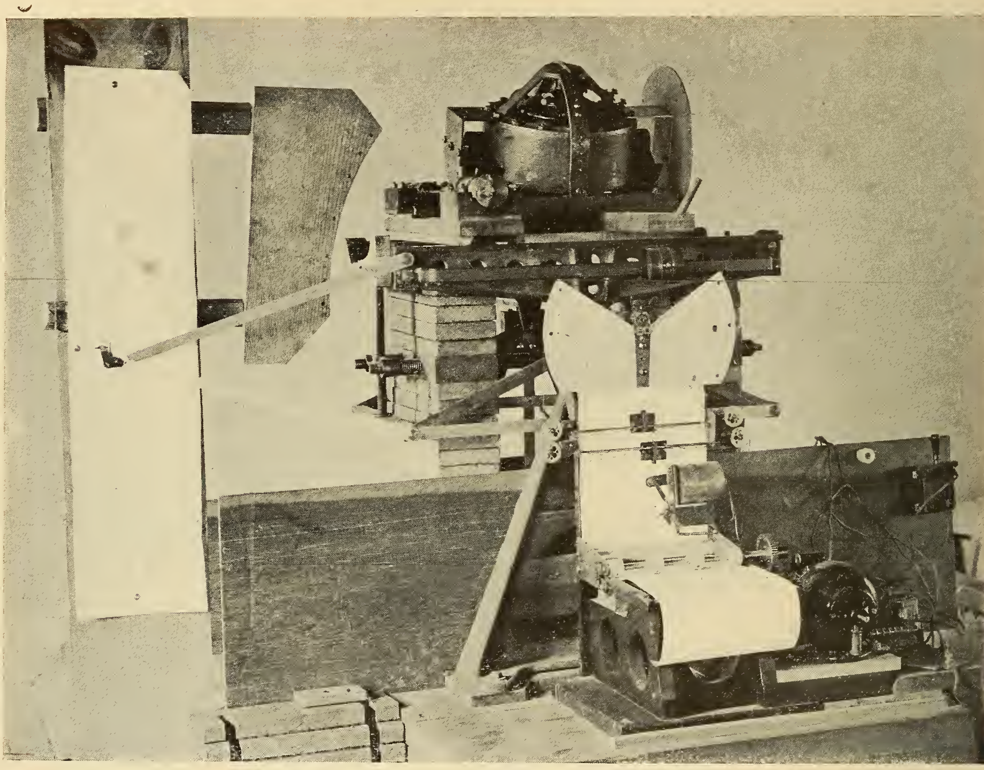
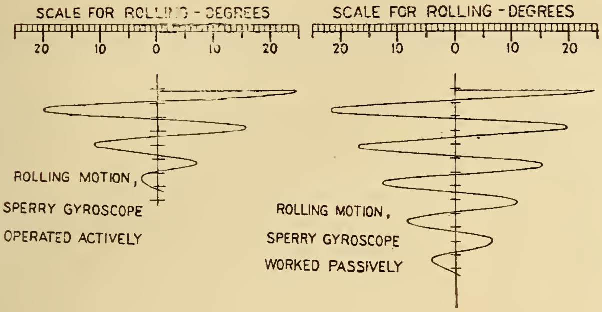


Fig. 6. Device for recording rolling motion of Ships

The slow athwartship or rolling motion of a ship exerts gyroscopic forces upon any vertical spinning shaft and in a fore-and-aft direction. These forces tend to dampen the rolling motion but only feebly, and the fore-and-aft reaction, owing to the absence of motion, does not have any effect at all. It is a part of the general plan to so utilize this force as to make it create extremely large reactions athwartships or in the proper direction to be effective. This is accomplished by the ingenious yet simple expedient of mounting the aforesaid vertical shaft in a pivoted frame, so that it can tilt and utilize the primary fore-and-aft reaction to cause the axis of the spinning mass to tilt fore and aft. This motion is of much higher velocity than the angular motion of the vessel which produces it. By means of this tilting motion an entirely new gyroscopic force is set up, again at right angles as in the first instance, but now to the plane of tilt (fore-and-aft) which brings it back to the original athwartship plane just where needed; and, what is equally important, the reaction is in a direction exactly opposed to the roll of the ship which primarily called it into action, as well as this whole chain of phenomena which has thus been traced through a complete cycle of 180 degrees of angle and also through an enormous augmentation of righting moment and stabilizing power.

The lecturer then called attention to a piece of apparatus consisting of a pendulum with a small gyroscope mounted on it (Fig. 5.). The spinning wheel of the gyroscope was revolved by means of a motor. It was seen that cords passed through two hollow gudgeons forming the axis of the pendulum and around horizontal pulleys which operated small pinions in the fork of the gyroscope; one being geared to the larger base ring shown in



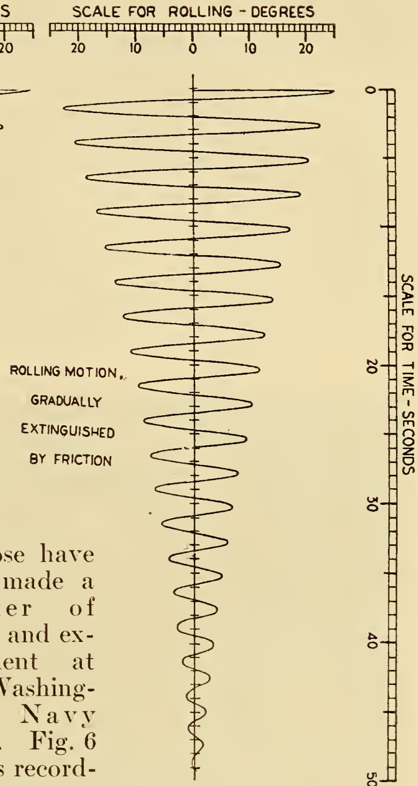


Fig. 7

the cut, and the other operating the inner or precessional ring through an intermediate miter segment. The cord passing through the axis of oscillation had no dampening effect whatever, and by means of these cords the gyroscope could be controlled. This method of control made the device what Mr. Sperry calls an "active" gyroscope, and by manipulating the cords the oscillation of the pendulum could be immediately stopped. When the speaker started the model without manipulating the cords, it is noticed that the device responded but feebly to small angles of oscillation, but freely and positively to the wide angles.

On battleships it is very necessary that the gunner should operate from a steady gun platform and, therefore, it becomes desirable to hold the ship on a practically even keel. The passive type of gyroscope does not accomplish what is desired, whereas the active type shown by the lecturer was capable of delivering to the boat stresses, equal and opposite, to those received by it from any source whatever.

In Sir John Thornicroft's gravity device, the weights alone had to be as great as five per cent. of the total displacement of the boat, to say nothing of the very large amount of hydraulic machinery needed for moving this weight. With an active gyroscope, one quarter of one per cent. of the displacement of the ship will practically extinguish the roll. By the use of this device, the ship can be made absolutely steady.

The size, weight, speed and location of the gyroscope most effective for this purpose have been made a matter of study and experiment at the Washington Navy Yard. Fig. 6 shows recording apparatus for a working model of a 26,000-ton battleship of the super-dreadnaught class, with a metacentric height of five feet and having a period of roll of eight seconds with a capacity of rolling through an arc of sixty degrees. The model was provided with this automatic recording device for the purpose of studying the motions of the ship and of the gyroscope. The latter was operated both passively and actively.

By means of this very complete equipment a great deal of valuable data was accumulated, much of which is new. The results appear to show that the active type of gyroscope will give much more perfect control of a ship than has been hitherto possible. Captain Taylor who made these tests has prepared a very full report in which he has gone into the mathematics of the gyroscope extensively.

Fig. 7 illustrates three curves: the one on the right gives the number of

oscillations of the ship's model before it was brought to rest by natural friction after it had been originally tilted twenty-five degrees; the short or central curve shows the number of oscillations when a steadying gyroscope was used acting passively on Doctor Schlick's plan; the still shorter curve at the left shows the number of oscillations of a ship being brought to rest by the same gyroscope when operated actively. These are among the interesting features in Captain Taylor's investigations. Some important installations of gyroscopes in ships are now being contemplated.

The principle that Mr. Brennan uses in his monorail railroad is interesting and ingenious. In the case of a spinning top which has partly lost its centrifugal force, and is leaning sharply as it describes its precessional orbit, if the rotation is accelerated by some mechanical contrivance, the top will assume a vertical position. This is the principle used by Mr. Brennan, who by means of a simple device automatically accelerates the precession of the rotating disk of his gyroscope thus preserving the equilibrium of his car.

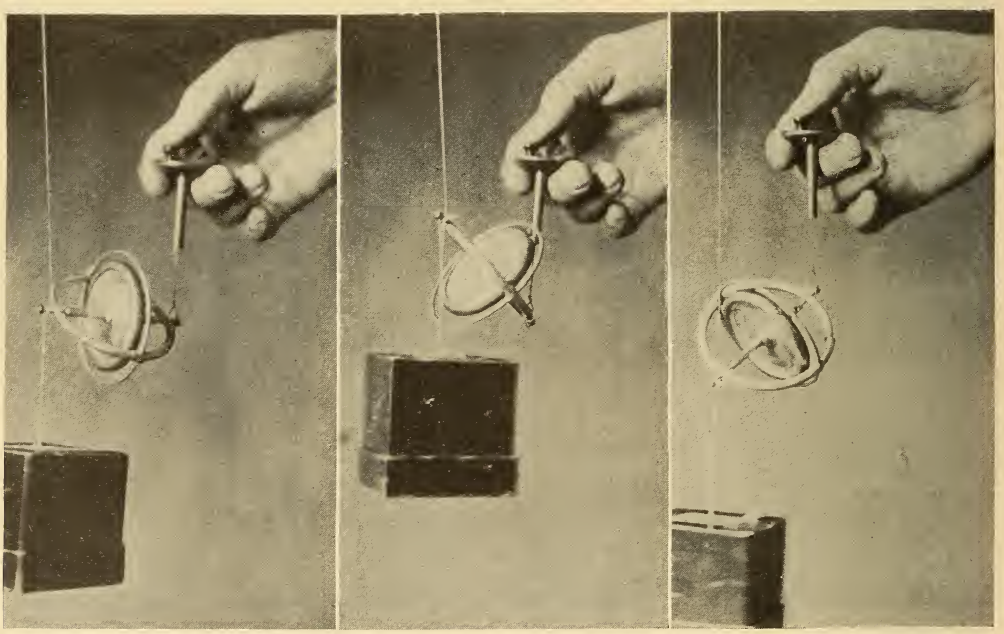


Fig. 8 Fig. 9 Fig. 10

The speaker showed experimental apparatus by means of which the precession of the gyroscope could be accelerated thus bringing it into a vertical position and when it was retarded it would fall.

In Fig. 8 is shown a simple gyroscope which has been spun up and which is revolving in its precessional course around a string as an axis. If now by means of a little wire we retard its precessional motion, there will be a reaction downward upon the entire system as is shown in Fig. 9. If, however, instead of retarding the precessional motion of the gyroscope about the string as an axis, the outer end of the device is pushed in the direction of its motion in the orbit it is describing, the gyroscope immediately rises as shown in Fig. 10. This is the whole principle of the Brennan monorail car which Mr. Sperry described in detail by means of lantern slides and by an operating model large enough to hold his son.

Mr. Brennan takes advantage of this law of the gyroscope to give stability to bodies in unstable equilibrium. In the experiments shown in Figs. 2, 3, and 4 it was noticed that change in the plane of the revolving bicycle wheel with a rim of lead tended to rotate the operator on his pivoted stool. The principle of the Brennan monorail car is identical with the one shown in the illustration. Fig. 11 shows the simplest form of the Brennan device taken from his patent specification. It consists of a car mounted on two wheels F and G having a platform with a frame in which is mounted vertically a spinning disk B. We will suppose that this disk is spun by an electric motor and that there is an operator on the platform with his hand on the handle H by means of which the gyroscope B may be turned either to the right or to the left. As in the case of the spinning top, so this car with its revolving gyroscope will tend to remain in the position shown. If for any cause such as the centrifugal force rounding a curve or an added weight on one side, the car should tend to fall over toward the reader, the operator on moving the handle H in the same direction will bring about a reaction tending to raise the car just as the gyroscope in Fig. 10 has been made to rise by accelerating its precessional motion, or as the stool was made to revolve by turning the bicycle fork. An operator on such a car could easily preserve its equilibrium indefinitely. Fig. 12 shows a Brennan device for automatically preserving equilibrium. M′ and M are two heavy spinning disks revolving on a horizontal axis R and supported in a frame V. T is an electric motor which revolves the disks. The whole system including disks, motor and frame can be moved about the axis 1–2 which is pivoted in a frame L. This frame has a movement about a horizontal axis at right angles to the axis of revolution of the gyroscope R as shown in the drawing. This movement, however, is restricted as only slight amplitude is necessary. The axis of revolution of the gyroscope is extended to the right and is provided with a friction roller 9. The casting of the frame V is also extended to the right and carries a friction roller 12. Above and below these rollers are horizontal guides 13–14–15–16 which form segments of circles, but which appear sectionally in the drawing. The segments are cut away at 15 and 14 as will be seen, so that the bearing surfaces are really at 13 and 16. These friction rollers have slight play between these guides. Now

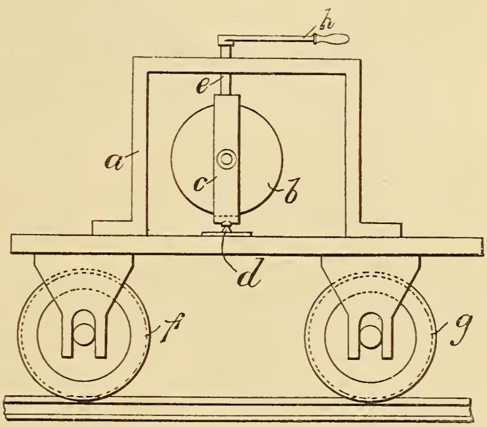


Fig. 11. Brennan's Monorail Car; hand operated

suppose the gyroscopes M′ and M are revolving rapidly and that the equilibrium of the vehicle is disturbed, we will say, by a tendency to fall toward the right in the direction of the arrow Z. As the gyroscope is mounted in a universal joint, it will tend to persist in its original position in space as the car falls. The falling of the car will press the guide 13 against the roller 9 and its pressure downward will cause a precession of the gyroscope causing the roller 9 to immediately move at right angles to the direction of the plane of the car, we will say toward the reader about the axis 1–2, but there is friction between the guide and the rapidly revolving roller 9 and this will accelerate the precession, the result of which is to cause the roller 9 to press the carriage back beyond the vertical position. As soon as the carriage passes the vertical position its weight tends to pull it farther over on the opposite side and the face of the guide 16 will then press against the roller 12

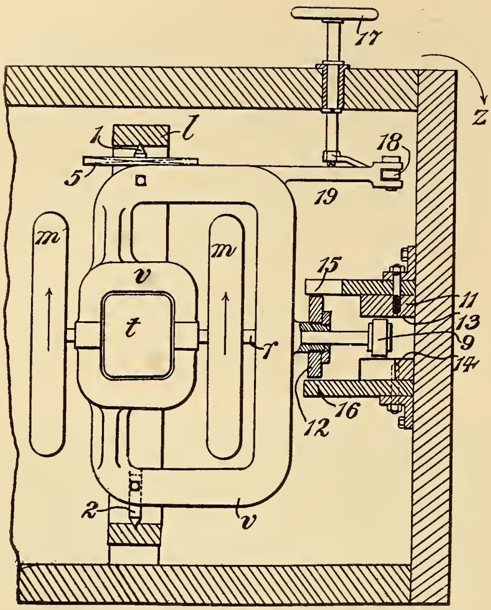


Fig. 12. Brennan's Automatic Control

causing a precession in the opposite direction. These movements are so very slight as to be almost unnoticed as the tendency of the apparatus is to keep the roller 9 in a normal position. The action does not tend to persist and to produce oscillations.

In practice two gyroscopes are used so geared that the movement of one frame about its axis produces an equal and opposite movement of the other.

Mr. Fröelich of Berlin, accelerates precession when it has once reached the center by a motor as shown in Fig. 13.

In regard to the monorail idea, Mr. Sperry said that although many engineers would prefer to send their families by two rails, rather than one, still there was a great deal to be said for the monorail. If it is to come, it will probably be because of popular pressure for much smoother transportation at high speeds than is possible with two rails. When railroad cars get to be very much larger with several decks, the monorail may be extensively used. There is no great saving in rail as the one rail is nearly as heavy as two rails would be and there is no economy in sleepers as they would have to be twice as close together. There would be no saving in excavation or tunnels. In fact, there would be no saving in the outlay. The quick laying of the railroad across a prairie and freedom from the necessity of running in a straight line, might make it valuable for war purposes.

Another use of the gyroscope which should be mentioned is in connection with the aëroplane. We have seen that with the use of a gyroscope an efficient balancing feature is introduced on the monorail car. The gyroscope provides a fulcrum in space as was shown in the episode of the Howell torpedo which persisted in holding its direction to the extent of turning a battleship.

With an exceedingly light gyroscope on an aëroplane, we can reduce the swing so that the oscillations will be extremely slow, thus giving the operator time to use the proper means of control. As Wilbur Wright has pointed out the

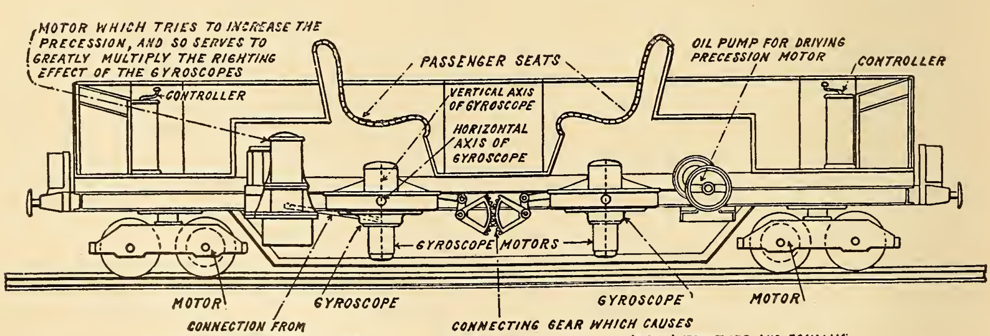


Fig. 13. Fröelich's Ballancing Device

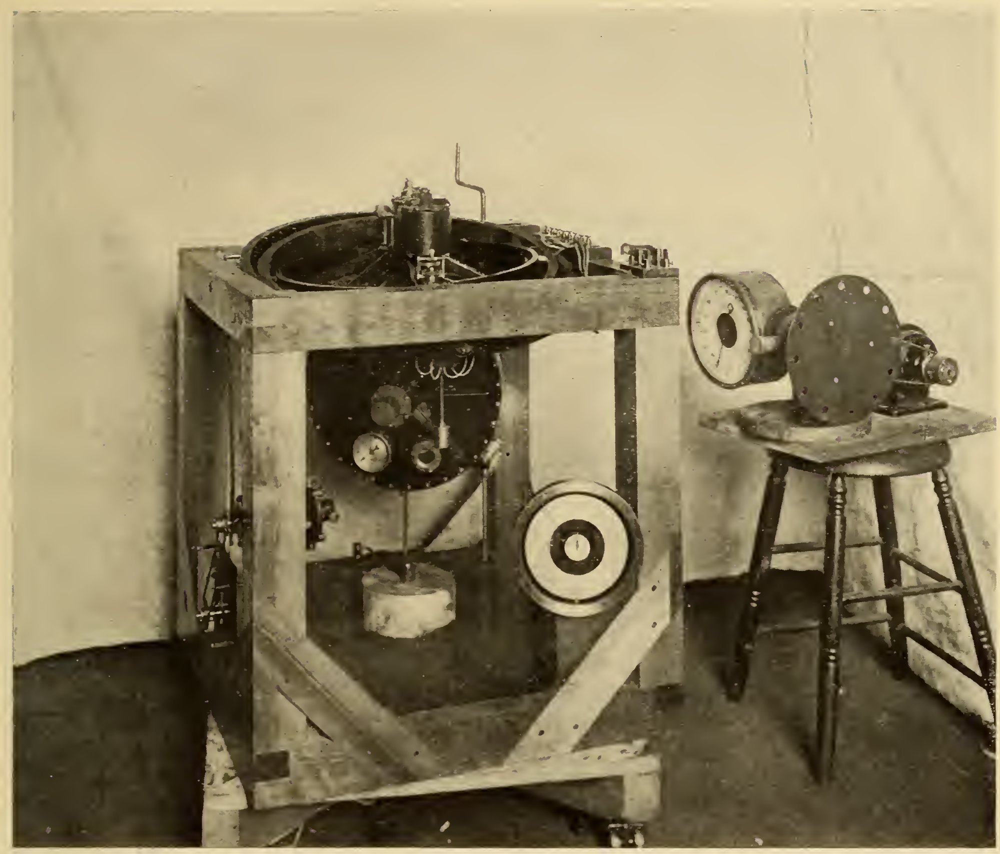


Fig. 14. Sperry's Battle Compass

dexterity required to manipulate an aëroplane takes it out of reach of inexpert hands. The airmen of the present day depend on their quickness of judgment, eye and hand to perform even the most ordinary evolutions in an aëroplane. The speaker said he had a gyroscope on an aëroplane that had been in the air a number of times with extremely satisfactory results.

Referring to the use of the gyroscope as a mariner's compass, the lecturer spoke of Foucault's experiments, who in 1852, after many attempts, finally succeeded in making apparatus so delicate in its construction as to demonstrate his proposition in the short period during which the disk revolved. Foucault exhibited this apparatus before the Royal Society in England where it aroused great enthusiasm.

Hopkins, an American, made a small electric-driven gyroscope compass in 1878 and more recently a German firm has equipped battleships with gyroscope compasses using mercury floats. There are many objections, however, to this form of construction. The action of the earth upon a spinning mass with a horizontal axis is such as to cause this mass to precess until its axis assumes a position parallel to that of the earth after which there is no further reaction, so that there is a very definite tendency to self-direction. In a gyroscope invented by Mr. Sperry this tendency amounts to a pull

of one ounce at a distance of four inches from the center, in an east and west direction at the equator. This tendency is a function of the latitude and ceases to operate at about 83 degrees. It is to be understood, of course, that the gryoscope compass points to the actual pole and not to the magnetic pole.

If the direction of a ship equipped with a Sperry compass be changed, forces are set up in the neighborhood of one hundred pounds at a radius of one foot which definitely oppose any tendency to change the position of the spinning axis. In this way, the directive factor when once established is held secure by a very strong force.

In equipping a battleship this compass would be placed below decks and small auxiliary instruments located in different positions on the ship. These auxiliary compasses would be controlled by the master compass in a secure location beyond reach of harm. The indications are accurate to a very small fraction of one degree.

Fig. 14 shows a Sperry master battle compass. It has been found that the auxiliary compasses require no cardian mounting and are accurate in any position. These compasses come nearer to being "dead beat" than air compasses for marine purposes, although they are not submerged, nor is any liquid used in connection with them. One of the points which has been achieved is the automatic correction of the northerly and southerly component of the vessel's speed at sea. This correction being made between the master compass and its auxiliaries in such a way that the latter maintain their direction toward the true geographical north. It will be understood that this type of compass is not affected in the slightest degree by the steel of the ship or the cargo, or by any magnetic disturbance. It is not affected by shifting cargo, turning turrets, or gun fire, nor by those disturbances of the magnetic compass technically known as deviation or variation.

ICE THAT WILL NOT FLOAT

There are four, possibly six different forms of ice. These may be divided into two groups, those forms that are lighter than water and those that are heavier. Under the first head come: Ordinary hexagonal ice, called ice 1, such as is formed on the window pane in winter or in snow; a form called ice 4; tetragonal ice, so called because of its crystalline form, observed by Nordenskiold; ice crystallizing in the regular system, observed by Barendrecht. Ice 4 is probably identical with one or other of the two latter forms.

If water is cooled very slowly the temperature may be lowered considerably under 0° C before the water freezes. Ice 4, which is slightly lighter than ordinary ice, is usually formed under these conditions. Increasing the pressure to several hundred atmospheres especially favors the formation of this variety of ice. It changes very readily into ice 1 and invariably does so if the pressure is released and the temperature is raised to nearly 0° C. Ice 1 is the stable form at all pressures under 2,200 atmospheres, if the temperature is not below —130 C.

If water is subjected to a pressure exceeding 2,500 atmospheres and the temperature is lowered sufficiently a solid, called ice 3, is formed. This form is heavier than water and sinks to the bottom. If the pressure is suddenly released ice 3 explodes into a white powder resembling snow which proves to be ice 1. Ice 2, which closely resembles and which readily turns into ice 3, may be formed by subjecting ice 1 at —80° C, to a pressure of 2,700 atmospheres.

It is interesting to note that a vessel filled with water will not burst when the water freezes if the vessel is capable of withstanding a pressure exceeding 2,500 atmospheres because ice 3 will be formed which takes up less room than the water itself. An article on ice 4, of which this is a digest will be found in *Zeitschrift für physikalische Chemie*, Vol. 72 (1910), page 609. E. B. S.

THE EXTENT OF THE UNIVERSE*

SPECULATION WITHIN THE LIMITS OF SOUND SCIENTIFIC REASONING WHICH SHOWS THAT OUR UNIVERSE HAS AN APPROXIMATE BOUNDARY

BY SIMON NEWCOMB

We cannot expect that the wisest men of our remotest posterity, who can base their conclusions upon thousands of years of accurate observation, will reach a decision on this subject without some measure of reserve. Such being the case, it might appear the dictate of wisdom to leave its consideration to some future age, when it may be taken up with better means of information than we now possess. But the question is one which refuses to be postponed so long as the propensity to think of the possibilities of creation is characteristic of our race. The issue is not whether we shall ignore the question altogether, like Eve in the presence of Raphael; but whether in studying it we shall confine our speculations within the limits set by sound scientific reasoning. Essaying to do this, I invite the reader's attention to what science may suggest, admitting in advance that the sphere of exact knowledge is small compared with the possibilities of creation, and that outside this sphere we can state only more or less probable conclusions.

The reader who desires to approach this subject in the most receptive spirit, should begin his study by betaking himself on a clear moonless evening, when he has no earthly concern to disturb the serenity of his thoughts, to some point where he can lie on his back on bench or roof, and scan the whole vault of heaven at one view. He can do this with the greatest pleasure and profit in late summer or autumn — winter would do equally well were it possible for the mind to rise so far above bodily conditions that the question of temperature should not enter. The thinking man who does this under circumstances most favorable for calm thought, will form a new conception of the wonder of the universe. If summer or autumn be chosen, the stupendous arch of the Milky Way will pass near the zenith, and the constellation Lyra, led by its beautiful blue Vega of the first magnitude, may be not very far from that point. South of it will be seen the constellation Aquila, marked by the bright Altair, between two smaller but conspicuous stars. The bright Arcturus will be somewhere in the west, and, if the observation is not made too early in the season, Aldebaran will be seen somewhere in the east. When attention is concentrated on the scene the thousands of stars on each side of the Milky Way will fill the mind with the consciousness of a stupendous and all-embracing frame, beside which all human affairs sink into insignificance. A new idea will be formed of such a well-known fact of astronomy as the motion of the solar system in space, by reflecting that throughout all human history, the sun carrying the earth with it has been flying toward a region in or just south of the constellation Lyra, with a speed beyond all that art can produce on earth, without producing any change apparent to ordinary vision in the aspect of the constellation. Not only Lyra and Aquila, but every one of the thousand stars which form the framework of the sky, were seen by our earliest ancestors just as we see them now. Bodily rest may be obtained at any time by ceasing from our labors, and weary systems may find nerve rest at any summer resort; but I know of no way in which complete rest can be obtained for the weary soul — in which the mind can be so entirely relieved of the burden of all human anxiety — as by the contemplation of the spectacle presented by the starry

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heavens under the conditions just described. As we make a feeble attempt to learn what science can tell us about the structure of this starry frame, I hope the reader will allow me at least to fancy him contemplating it in this way.

The first question which may suggest itself to the inquiring reader is: How is it possible by any method of observation yet known to the astronomer to learn anything about the universe as a whole? We may commence by answering this question in a somewhat comprehensive way. It is possible only because the universe, vast though it is, shows certain characteristics of a unified and bounded whole. It is not a chaos, it is not even a collection of things, each of which came into existence in its own separate way. If it were, there would be nothing in common between two widely separate regions of the universe. But, as a matter of fact, science shows unity in the whole structure, and diversity only in details. The Milky Way itself will be seen by the most ordinary observer to form a single structure. This structure is, in some sort, the foundation on which the universe is built. It is a girdle which seems to span the whole of creation, so far as our telescopes have yet enabled us to determine what creation is; and yet it has elements of similarity in all its parts. What has yet more significance, it is in some respects unlike those parts of the universe which lie without it, and even unlike those which lie in that central region within it where our system is now situated. The minute stars, individually far beyond the limit of visibility to the naked eye, which form its cloudlike agglomerations, are found to be mostly bluer in color, from one extreme to the other, than the general average of the stars which make up the rest of the universe.

There are two points in the sky called poles of the Milky Way, which bear the same relation to it that the north and south poles of the earth bear to the equator: they lie in opposite directions and are each 90° from the central line of the milky arch. The careful counts of stars made since the time of the Herschels show that, as a general rule, there are fewest stars on a given surface of the sky round the galactic poles (as those of the Milky Way are called) and that their thickness gradually increases as we approach the great girdle itself. This feature of the sky will, with a little care, be evident even to the observer without a telescope, who will see that the stars are somewhat more numerous along the outskirts of the Milky Way than around its poles. The regions of the heavens occupied by the poles of the Milky Way are as far apart as two points in the sky can be. And yet, the most careful counts of the stars show that, although they are fewer in number around these poles than elsewhere, they are about equally thick in these two opposite directions. For every point in the sky there is an opposite point, one of the two being below the horizon when the other is above it. The relation is that of our antipodes to us. It is a noteworthy feature of the universe that a certain resemblance is found in any two opposite regions of the sky, no matter where we choose them. If we take them in the Milky Way, the stars are more numerous than elsewhere; if we take opposite regions in or near the Milky Way, we shall find more stars in both of them than elsewhere; if we take them in the region anywhere around the poles of the Milky Way, we shall find fewer stars, but they will be equally numerous in each of the two regions. We infer from this that whatever cause determined the number of the stars in space was of the same nature in every two antipodal regions of the heavens.

Another unity marked with yet more precision is seen in the chemical elements of which stars are composed. We know that the sun is composed of the same chemical elements which we find on the earth and which we resolve in our laboratories. These same elements are found in the most distant stars. It is true that some of these bodies seem to contain elements which we do not find on earth. But as these unknown

elements are scattered from one extreme of the universe to the other, they only serve still farther to enforce the unity which runs through the whole. The nebulæ are composed, in part at least, of forms of matter dissimilar to any with which we are acquainted. But, different though they may be, they are alike in their general character throughout the whole field we are considering. Even in such a feature as the proper motions of the stars, the same unity is seen. The reader doubtless knows that each of these objects is flying through space on its own course with a speed comparable with that of the earth around the sun. These speeds range from the smallest limit up to more than one hundred miles a second. Such diversity might seem to detract from the unity of the whole; but when we seek to learn something definite by taking their average, we find this average to be, so far as can yet be determined, much the same in opposite regions of the universe. Quite recently it has become probable that a certain class of very bright stars known as Orion stars — because there are many of them in the most brilliant of our constellations — which are scattered along the whole course of the Milky Way, have one and all, in the general average, slower motions than other stars. Here again we have a definable characteristic extending through the universe. In drawing attention to these points of similarity throughout the whole universe, it must not be supposed that we base our conclusions directly upon them. The point they bring out is that the universe is in the nature of an organized system; and it is upon the fact of its being such a system that we are able, by other facts, to reach certain conclusions as to its structure, extent, and other characteristics.

One of the great problems connected with the universe is that of its possible extent. How far away are the stars? One of the unities which we have described leads at once to the conclusion that the stars must be at very different distances from us; probably the more distant ones are a thousand times as far as the nearest; possibly even farther than this. This conclusion may, in the first place, be based on the fact that the stars seem to be scattered equally throughout those regions of the universe which are not connected with the Milky Way. To illustrate the principle, suppose a farmer to sow a wheat-field of entirely unknown extent with ten bushels of wheat. We visit the field and wish to have some idea of its acreage. We may do this if we know how many grains of wheat there are in the ten bushels. Then we examine a space two or three feet square in any part of the field and count the number of grains in that space. If the wheat is equally scattered over the whole field, we find its extent by the simple rule that the size of the field bears the same proportion to the size of the space in which the count was made that the number of grains sown bears to the number of grains counted. If we find ten grains in a square foot, we know that the number of square feet in the whole field is one tenth of the number of grains sown. So it is with the universe of stars. If the latter are sown equally through space, the extent of the space occupied must be proportional to the number of stars which it contains.

But this consideration does not tell us anything about the actual distance of the stars or how thickly they may be scattered. To do this we must be able to determine the distance of a certain number of stars, just as we suppose the farmer to count the grains in a certain small extent of his wheat-field. There is only one way in which we can make a definite measure of the distance of any one star. As the earth swings through its vast annual circuit round the sun, the direction of the stars must appear to be a little different when seen from one extremity of the circuit than when seen from the other. This difference is called the parallax of the stars; and the problem of measuring it is one of the most delicate and difficult in the whole field of practical astronomy.

The nineteenth century was well on its way before the instruments of the astronomer were brought to such per-

fection as to admit of the measurement. From the time of Copernicus to that of Bessel many attempts had been made to measure the parallax of the stars, and more than once had some eager astronomer thought himself successful. But subsequent investigation always showed that he had been mistaken, and that what he thought was the effect of parallax was due to some other cause, perhaps the imperfections of his instrument, perhaps the effect of heat and cold upon it or upon the atmosphere through which he was obliged to observe the star, or upon the going of his clock. Thus things went on until 1837, when Bessel announced that measures with a heliometer—the most refined instrument that has ever been used in measurement—showed that a certain star in the constellation Cygnus had a parallax of one third of a second. It may be interesting to give an idea of this quantity. Suppose oneself in a house on top of a mountain looking out of a window one foot square at a house on another mountain one hundred miles away. One is allowed to look at that distant house through one edge of the pane of glass and then through the opposite edge; and he has to determine the change in the direction of the distant house produced by this change of one foot in his own position. From this he is to estimate how far off the other mountain is. To do this, one would have to measure just about the amount of parallax that Bessel found in his star. And yet this star is among the few nearest to our system. The nearest star of all, Alpha Centauri, visible only in latitudes south of our middle ones, is perhaps half as far as Bessel's star, while Sirius and one or two others are nearly at the same distance. About one hundred stars, all told, have had their parallax measured with a greater or less degree of probability. The work is going on from year to year, each successive astronomer who takes it up being able, as a general rule, to avail himself of better instruments or to use a better method. But after all, the distances of even some of the one hundred stars carefully measured must still remain quite doubtful.

One general result of these measures of parallax may be set forth in this way: Imagine round our solar system as a centre (for in matters relating to the universe our whole system is merely a point), a sphere with a radius 400,000 times the distance of the sun. An idea of this distance may be gained by reflecting that light, making the circuit of the earth seven times in a second, and reaching us from the sun in eight minutes and twenty seconds, would require seven years to reach the surface of the sphere we have supposed. Now, the first result of measures of parallax is that within this enormous sphere there is, besides our sun in the centre, only a single star; namely, Alpha Centauri.

Now suppose another sphere, having a radius 800,000 times the distance of the sun, so that its surface is twice as far as that of the inner sphere. By the law of cubes the volume of space within this second sphere is eight times as great as that within the first. So far as can be determined, there are about eight stars within this sphere. We cannot be quite sure of the number, because there may be stars within the sphere of which the parallax is not yet detected; and of those supposed to be within it, one or two are so near the surface that we cannot say whether they are really within or without it. But the number eight is not egregiously in error.

We may imagine the spheres extended in this way indefinitely, but the result for the number of stars within them becomes uncertain owing to the increasing difficulties of measuring parallaxes so minute. The general trend of such measures up to the present time is that the number of stars in any of these spheres will be about equal to the units of volume which they comprise when we take for this unit the smallest and innermost of the spheres, having a radius 400,000 times the sun's distance. We are thus enabled to form some general idea of how thickly the stars are sown through space. We cannot claim any numerical exactness for this idea, but in the absence of better methods it does afford us some basis for reasoning.

Now we can carry on our computation as we supposed the farmer to measure the extent of his wheat-field. Let us suppose that there are 125,000,000 stars in the heavens. This is an exceedingly rough estimate, but let us make the supposition for the time being. Accepting the view that they are nearly equally scattered throughout space, it will follow that they must be contained within a volume equal to 125,000,000 times the sphere we have taken as our unit. We find the distance of the surface of this sphere by extracting the cube root of this number, which gives us 500. We may, therefore, say, as the result of a very rough estimate, that the number of stars we have supposed would be contained within a distance found by multiplying 400,000 times the distance of the sun by 500; that is, that they are contained within a region whose boundary is 200,000,000 times the distance of the sun. This is a distance through which light would travel in about 3300 years.

It is not impossible that the number of stars is much greater than we have supposed. Let us grant that there are eight times as many, or one thousand millions. Then we should have to extend the boundary of our universe twice as far, carrying it to a distance which light would require 6,600 years to travel.

There is another method of estimating the thickness with which stars are sown through space, and hence the extent of the universe, the result of which will be of interest. It is based on the proper motion of the stars. One of the greatest triumphs of astronomy of our time has been the measurement of the actual speed at which many of the stars are moving to or from us in space. These measures are made with the spectroscope. Unfortunately, they can be best made only on the brighter stars—at least, those plainly visible to the naked eye. Still the motions of several hundreds have been measured and the number is constantly increasing.

A certain general result of all these measures and of other estimates may be summed up by saying that there is a general average speed with which the individual stars move in space, and that this average is about twenty miles per second. We are also able to form an estimate as to what proportion of the stars move with each rate of speed from the lowest up to a limit which is probably as high as 150 miles per second. Knowing these proportions we have, by observation of the proper motions of the stars, another method of estimating how thickly they are scattered in space; in other words, what is the volume of space which, on the average, contains a single star. This method gives a thickness of the stars greater by about twenty-five to fifty per cent. than that derived from the measures of parallax. That is to say, a sphere like the second we have proposed, having a radius 400,000 times the distance of the sun, and therefore a diameter 800,000 times this distance, would, judging by the proper motions, have ten or twelve stars contained within it, while the measures of parallax only show eight stars within the sphere of this diameter having the sun as its centre. The probabilities are in favor of this last result. But, after all, the discrepancy does not change the general character of the conclusion as to the limits of the visible universe. If we cannot estimate its extent with the same certainty that we can determine the size of the earth, we can still form a general idea of it.

The estimates we have made are based on the supposition that the stars are equally scattered in space. We have good reason to believe that this is true of all the stars except those of the Milky Way. But, after all, the latter probably includes half the whole number of stars visible with a telescope, and the question may arise whether our results are seriously wrong from this cause. This question can best be solved by yet another method of estimating the average distance of certain classes of stars.

The parallaxes of which we have heretofore spoken consist in the change in the direction of a star produced by the swing of the earth from one side of its orbit to the other. But we have al-

ready remarked that our solar system, with the earth as one of its bodies, has been journeying straight forward through space during all historic times. It follows, therefore, that we are continually changing the position from which we view the stars, and that, if the latter were at rest, we could, by measuring the apparent speed with which they are moving in the opposite direction from that of the earth, determine their distance. But since every star has its own motion, it is impossible, in any one case, to determine how much of the apparent motion is due to the star itself, and how much to the motion of the solar system through space. Yet, by taking general averages among groups of stars, most of which are probably near each other, it is possible to estimate the average distance by this method. When an attempt is made to apply it, so as to obtain a definite result, the astronomer finds that the data now available for the purpose are very deficient. The proper motion of a star can be determined only by comparing its observed position in the heavens at two widely separate epochs. Observations of sufficient precision for this purpose were commenced about 1750 at the Greenwich Observatory, by Bradley, then Astronomer Royal of England. But out of 3,000 stars which he determined, only a few are available for the purpose. Even since his time, the determinations made by each generation of astronomers have not been sufficiently complete and systematic to furnish the material for anything like a complete determination of the proper motions of stars. To determine a single position of any one star involves a good deal of computation, and if we reflect that, in order to attack the problem in question in a satisfactory way, we should have observations of a million of these bodies made at intervals of at least a considerable fraction of a century, we see what an enormous task the astronomers dealing with this problem have before them, and how imperfect must be any determination of the distance of the stars based on our motion through space. So far as an estimate can be made, it seems to agree fairly well with the results obtained by the other methods. Speaking roughly, we have reason, from the data so far available, to believe that the stars of the Milky Way are situated at a distance between 100,000,000 and 200,000,000 times the distance of the sun. At distances less than this it seems likely that the stars are distributed through space with some approach to uniformity. We may state as a general conclusion, indicated by several methods of making the estimate, that nearly all the stars which we can see with our telescopes are contained within a sphere not likely to be much more than 200,000,000 times the distance of the sun.

The inquiring reader may here ask another question. Granting that all the stars we can see are contained within this limit, may there not be any number of stars without the limit which are invisible only because they are too far away to be seen?

This question may be answered quite definitely if we grant that light from the most distant stars meets with no obstruction in reaching us. The most conclusive answer is afforded by the measure of starlight. If the stars extended out indefinitely, then the number of those of each order of magnitude would be nearly four times that of the magnitude next brighter. For example, we should have nearly four times as many stars of the sixth magnitude as of the fifth; nearly four times as many of the seventh as of the sixth, and so on indefinitely. Now, it is actually found that while this ratio of increase is true for the brighter stars, it is not so for the fainter ones, and that the increase in the number of the latter rapidly falls off when we make counts of the fainter telescopic stars. In fact, it has long been known that, were the universe infinite in extent, and the stars equally scattered through all space, the whole heavens would blaze with the light of countless millions of distant stars separately invisible even with the telescope.

The only way in which this conclusion can be invalidated is by the possi-

bility that the light of the stars is in some way extinguished or obstructed in its passage through space. A theory to this effect was propounded by Struve nearly a century ago, but it has since been found that the facts as he set them forth do not justify the conclusion, which was, in fact, rather hypothetical. The theories of modern science converge toward the view that, in the pure ether of space, no single ray of light can ever be lost, no matter how far it may travel. But there is another possible cause for the existence of light. During the last few years discoveries of dark and therefore invisible stars have been made by means of the spectroscope with a success which would have been quite incredible a very few years ago, and which, even today, must excite wonder and admiration. The general conclusion is that, besides the shining stars which exist in space, there may be any number of dark ones, forever invisible in our telescopes. May it not be that these bodies are so numerous as to cut off the light which we would otherwise receive from the more distant bodies of the universe? It is of course impossible to answer this question in a positive way, but the probable conclusion is a negative one. We may say with certainty that dark stars are not so numerous as to cut off any important part of the light from the stars of the Milky Way, because, if they did, the latter would not be so clearly seen as it is. Since we have reason to believe that the Milky Way comprises the more distant stars of our system, we may feel fairly confident that not much light can be cut off by dark bodies from the most distant region to which our telescopes can penetrate. Up to this distance we see the stars just as they are. Even within the limit of the universe as we understand it, it is likely that more than one half the stars which actually exist are too faint to be seen by human vision, even when armed with the most powerful telescopes. But their invisibility is due only to their distance and the faintness of their intrinsic light, and not to any obstructing agency.

The possibility of dark stars, therefore, does not invalidate the general conclusions at which our survey of the subject points. The universe, so far as we can see it, is a bounded whole. It is surrounded by an immense girdle of stars, which, to our vision, appears as the Milky Way. While we cannot set exact limits to its distance, we may yet confidently say that it is bounded. It has uniformities running through its vast extent. Could we fly out to distances equal to that of the Milky Way, we should find comparatively few stars beyond the limits of that girdle. It is true that we cannot set any definite limit and say that beyond this nothing exists. What we can say is that the region containing the visible stars has some approximation to a boundary. We may fairly anticipate that each successive generation of astronomers, through coming centuries, will obtain a little more light on the subject—will be enabled to make more definite the boundaries of our system of stars, and to draw more and more probable conclusions as to the existence or non-existence of any object outside of it. The wise investigator of today will leave to them the task of putting the problem into a more positive shape.

LECTURES FOR JANUARY

The lecturers before the Society of Arts in January will probably be Dr. Ernest F. Nichols, President of Dartmouth College on "Light Pressure," and Professor William T. Sedgwick, head of the Department of Biology at the Institute, on "Science in the Social Organism." These will be announced in the January number of the Science Conspectus.

THE REALITY OF ATOMS

EXTRAORDINARY EXPERIMENTAL RESULTS ACHIEVED BY RUTHERFORD AND MILLIKAN—VISIBLE EFFECTS PRODUCED BY A SINGLE ATOM

BY D. F. COMSTOCK

As everyone knows it has long been a fundamental conception in science that every piece of matter is an aggregate of ultimate particles which are known as atoms. This conception has been so fruitful in its results that the so-called atomic theory has seemed to express the actual truth with a high degree of probability. Of course these atoms must be considered so small that they are beyond reach of the most powerful microscope and hence cannot, and perhaps never will, be seen directly, and therefore in recent years there has come into the minds of some thinkers the idea that, perhaps after all, the atomic theory is only symbolic in its actual nature and, although useful, does not correspond to any ultimate reality.

Within the last few years, however, three extraordinary experimental results have been achieved which have completely suppressed the doubters and have so completely routed them that they are almost certain never to return to their battlements. The first result referred to, grew out of the infant science of radio-activity. The second was an experimental result brought about by the genius of Ernest Rutherford, the distinguished pioneer in radio-activity and the third is a result obtained within the last year by a countryman of our own, Professor Millikan of the University of Chicago. In every one of these cases a definite visible effect was produced by the action of a single atom or molecule, that is, in each of these three remarkable instances, the experiments were so arranged that one could, so to speak, count the atoms one by one. Such an attainment is remarkable and quite unique. In all the history of physics before, there was not a single effect noticed which could be attributed directly to an action of a single atom or molecule. In all cases experimental results were of such a nature that it indeed seemed necessary to interpret them by assuming matter to be made up of these ultimate units, but this assumption, although probable, lacked direct proof and was very far from being equivalent to the isolation of a single atom or molecule. Thus the atomic theory, although a highly probable one, had to wait until within the last few years for its proof, but this proof, when it came placed it beyond all reasonable doubt.

Inasmuch as this experimental proof of the atomic concept is of momentous import in the scientific world, it will, perhaps, be of interest to the reader if we outline as briefly as possible, the nature of the evidence in these three types of fundamental experiment.

As has been said, the first of these three results grew out of the science of radio-activity not long after its birth. If a piece of radio-active material be held near a piece of zinc sulphide, it will be found that the sulphide is caused to phosphoresce brightly. This phosphorescence has been found to be due almost entirely to what are known as the "alpha rays" from the radio-active substance. Following out the atomic theory these rays have been assumed to be atoms of the element helium, but, of course, if the whole idea of atoms is fallacious, then the presumption as to the nature of alpha rays is wide of the mark. The remarkable thing, however, in connection with the phosphorescence caused by the alpha rays is that if the lighted region is examined closely with a lens, it is found to be not the uniformly illuminated surface which it appears to the naked eye, but instead a region of darkness illuminated by thousands of

little bright stars each one of which exists only for an instant and then vanishes. Such an effect can only be interpreted as due to the bombardment of a stream of separate particles which leave the radio-active substance and impinge upon the piece of sulphide causing it to phosphoresce at one minute point wherever one of these particles strikes. Here we have a light effect due to the striking of a single atom and as has been intimated, it is the very first result of the kind in the history of physics. By counting the number of the scintillations one can tell how many atoms leave the radio-active substance per second.

And now let us speak briefly of the second experiment of this famous trio. It was known when Professor Rutherford commenced his study that one of the particles assumed to make up the alpha rays travels with such enormous speed that it produces heating effects when stopped which are out of all proportion to its size. In more technical terms, it was known that a so-called "alpha particle" produced some eighty thousand ions in the air or other gas which it passed through before it was slowed down like a meteor and finally stopped. Now these ions which are formed in the gas are similar to the ions in an electrolytic solution and by their presence they cause the gas to be a very much better conductor of electricity than it was before. Moreover, by properly arranging the apparatus, it is possible to cause these eighty thousand ions to move so rapidly by means of an electric field that each of them will produce perhaps a thousand more ions by the same general bombarding action as that of the original alpha particle. Thus it will be evident in a general way that the effect of a single alpha particle might by proper arrangement be so enormously magnified by this double multiplication of effects that the end result might be great enough to affect a needle of the most delicate electrometer known. Now this is just the idea which came to Professor Rutherford and he arranged his apparatus so that a minute particle of radio-active material emitted its rays in the direction of a distant hole in a piece of metal. The hole was so small and so distant that, on the average, he calculated that only about four single particles in the rays would pass through this hole in a minute. On the other side of the hole he had his magnifying apparatus set up, including his extremely delicate electric detector (electrometer), and he finally succeeded in getting a definite jerk to the needle of this instrument for every single alpha particle which came through the small hole, that is, on the average about four jerks a minute. Thus he was enabled to count one by one the ultimate particles of which the rays are built up, and the result was the same as the number of scintillations before mentioned. It has been shown definitely that radium gives off the element helium continually, and as a matter of fact, it is known that this helium comes off in the form of these same alpha rays, so that when we discover that the rays are composed of a stream of separate particles and when we have counted these, we have in reality counted the actual atoms of helium as they enter our apparatus one by one. This result it was which broke down finally the opposition of those opposing the atomic theory.

And now we come to the third experiment; namely, that of Professor Millikan. It has been shown in recent years, that electricity and matter in their ultimate structure are very closely akin and, indeed, electricity as well as matter, is atomic in its nature, that is, electricity is no more uniform and continuous than matter, but consists of ultimate units called electrons which are not further divisible. When the so-called ions are produced in the gas, the action is simply that of detaching an atom of electricity from an atom of matter and allowing it either to float free, or attach itself to another molecule of the gas. Now Professor Millikan succeeded in getting one of these ions or charged molecules, let us say, completely isolated from the rest, and was thus enabled to study the effect of elec-

tric attractions or repulsions upon one single atom of electricity and measure accurately the value of its charge in terms of everyday laboratory units. He did this by a method first conceived by Sir J. J. Thomson, the great pioneer in modern physics. It had been found by Thomson and others, that when fog is produced in damp air which contains ions, the ions assume the rôle of nuclei about which fog particles form. The ions themselves are thousands of times too small to be seen even with a microscope, but when a fog particle, that is a small drop of water, is formed about an ion, Millikan found it perfectly possible to see and observe the motions of a single drop having as its nucleus a single ion. Such a small drop of water having an electric charge equal to a single atom of electricity will, of course, be slowly attracted or repelled from a large charge brought near to it in the room and its motions under changing conditions may be carefully observed and studied. It might readily happen, of course, that such a charged drop would acquire another atom of electricity of the same sign as the first, because of the proximity of the many ions both positive and negative in the surrounding gas. As a matter of fact, Professor Millikan noticed over and over again the sudden increase in the speed with which his little water drop was moving, corresponding to the sudden increase of its charge through the capture of another ion. Throughout the long series of experiments on many drops of water and oil, he actually saw the little drop through the sudden change of its speed take on ion after ion, one at a time. The increase in speed throughout the whole series being of such amount as to be in perfect harmony with preconceived ideas as to the size of the ultimate atom of electricity.

Thus to sum up in a few words, Professor Millikan saw a minute drop of water or oil increase or diminish its speed in jerks corresponding to its taking on one by one a series of atoms of electricity, thus demonstrating with renewed force the discontinuous structure of electricity and the validity of modern ideas with regard to the actual magnitude of this ultimate unit.

There are doubtless many people to whom these fundamental experiments will not appear particularly remarkable, but to the scientific man accustomed to think of the extraordinary minuteness of the atom which has long been such a fundamental concept, these experiments can be considered little short of epoch making. It will give some vague idea of what it means to count atoms one by one, to say that in a cubic inch of water, there are so many atoms that the number can only be represented by a figure of twenty-five ciphers.

MOTION PICTURES IN NATURAL COLORS

At a recent meeting of the New York Electrical Society some beautiful effects were shown with the new process of producing moving pictures in natural colors produced by a photographic process and not by any retouching of the negative. The effect is said to be indescribably beautiful to those who have seen the new process. By taking pictures at intervals of fifteen to thirty minutes and then reproducing them with the rapidity of sequence of ordinary moving pictures, flower buds can be seen to swell and blossom before the very eyes of the spectator and in the most wonderful colors imaginable. In this process, two color filters are used: one for red and the other for green and also highly sensitized films. The pictures are taken about twice as rapidly as ordinary moving pictures and are reproduced in the same way. The films are ordinary black and white films and the color effects are produced by red and green screens placed just back of the lens. The first picture shown on the screen is red, then comes one of green, then one of red and so on, the alternations being so rapid that the effect on the eye is that of the natural blending of color and motion.

KARL PEARSON ON PRACTICAL EUGENICS

FACTORY LEGISLATION AND MODERN CHARITY PENALIZE GOOD PARENTAGE — THE REMEDY BESET WITH GRAVE DIFFICULTIES

BY SELSKAR M. GUNN

The decrease of the birth rate in England, France and other countries has been the subject of considerable discussion during the past few years, and Prof. Karl Pearson, of the Francis Galton Eugenics Laboratory in London, in a lecture delivered on May 25, 1909, discussed certain features of the problem with reference to English conditions, which are of general interest. Professor Pearson's reputation as a scientist is international and his opinions are therefore worthy of close attention.

Factory legislation, prohibiting and restricting child labor and the working of mothers for considerable periods both before and after the birth of children, is considered by Professor Pearson to be in a large measure, responsible for the decrease in the birth rate, and furthermore, he states that, "legislation devoted to the improvement of the race by change of environment, may not only be ineffectual, but may be positively detrimental, if its result be to modify selective action."

Professor Pearson emphasizes that children of the "working class" used to have a distinct economic value, but they can no longer be considered as an economic asset since both factory acts, with child labor restrictions, and education acts, with compulsory attendance rules, have taken away their value, and a voluntary curtailment of the number of children has resulted, as children were no longer financially profitable.

He sets out to prove this statistically, and figures, which have been gathered from certain mining, rural and industrial parts of England are given. He notes that following every particular act that restricted child labor or required compulsory attendance, there has been a marked accelerated decadence in the birth rate. At the present time the child has no economic value till it is 13 and 14, and even then, on account of restrictions, it is of limited productivity until 16.

The decreased birth rate also emphasizes a biological feature of much importance. Observations, which he believes to be correct, demonstrate "that the mental and physical condition of the first and second born members of a family is differentiated from that of later members. They are of a more nervous and less stable constitution. We find that the neurotic, the insane, the tuberculous and the albinotic are more frequent among the elder born."

The significance of this fact, if true, is most vital, as it means that with reduction of size of family, there arises an increased relative proportion of the mentally and physically unsound in a community.

With regard to the legislation of the kind mentioned above, Professor Pearson states "that we have an illustration in this matter of a case—and it is not an isolated case—in which legislation intended to promote national progress—to improve the racial qualities of future generations—has directly tended to enfeeble the race; in the first place by reducing the intensity of natural selection, and in the second place by producing a population of lower average fitness."

The reason for this is attributed to the fact "that one class which had no experience of the child as an economic asset was legislating for another whose life conditions the former did not in the least realize."

Parents are actually handicapped in the struggle for existence as against the childless couple, as they have increased

expenses, but no augmentation of income.

Statistics are given to show that, even with a markedly lower birth rate, there is a correlation of the higher grades of this lower birth rate with socially undesirable characters. High birth rates have a very marked relation to bad characteristics, the only exception to this that was noted was with cancer; here the districts of good social character but with low birth rates, have the most cancer.

Furthermore, he considers that modern charity and poor laws have tended to directly penalize good parentage. He says that "the child ceasing to be an economic asset, has become a burden; but poor laws and charity have largely succeeded in lifting this burden from the shoulders of the *degenerate* parent."

Professor Pearson does not advocate in any way the repeal of factory acts and the return of the children to the insanitary and stifling atmosphere of the workshops. He believes that the problem can largely be solved by giving back to the child its economic value, "and if we can differentiate between the economic values of good and bad parentage, if we can make the possession of healthy, sound children a greater economic asset than the possession of feeble offspring, then we have for the mass of the people solved the problem of practical eugenics."

He further believes that there is one way in which the problem can be solved, and this depends on the reversal of the effects of the present factory acts which penalize parentage and handicap motherhood, and this must be done in such a way "that sound parentage and healthy motherhood must be given a substantially economic advantage over, not only childlessness, but over unsound parentage and feeble motherhood."

The author realizes the grave difficulties in bringing about the changes that will remove the penalty for good parentage. State endowment of fit parentage is suggested as a possibility, and Professor Pearson suggests that the millions of pounds now being given to old age pensions could be used to better advantage in endowing parentage instead of senility, but he does not yet see light towards the practical solution of the problem "except in a system of national insurance, in which employer, state and workmen shall combine to insure against invalidity, motherhood and the nurture of offspring—such provision being differentiated by the fitness of the parentage."

Environmental reform and philanthropic effort in the last sixty years in England has done much to interfere with the process of natural selection and consequently with the selective death rate. If the former racial stability and national stamina of the English is to be regained, Professor Pearson believes that a selective birth rate must be introduced to offset the evil effects of the suspension of the selective death rate.

Professor Pearson does not anticipate that the fundamental principle of his lecture, namely that the child is a ware and of economic value, will be a popular doctrine. It will be particularly disagreeable to the cultured classes, with whom the child has never been a monetary asset. He believes, however, that with a realization of the great social principles involved, the prejudices and difficulties will be surmounted.

The above is in no sense a critical review, but merely an abstract of a lecture which seemed to be of unique interest and of possible application to certain districts and cities in the United States.

The full lecture will be found in No. 5 of the Eugenics Laboratory Lecture Series published by Dulau & Co., of London.

NEW DISCOVERY IN SOIL FERTILIZATION

Any discovery or application of science that has to do with the improvement of the fertility of the soil, naturally warrants unusual interest and a recent communication from the Rothamsted Experiment Station at Harpenden, England, indicates that another step in advance has been made and that we are coming to a better understanding of the chemical and biological conditions existing in the soil.

It has been known since 1878 that the process of nitrification in soil is due to living agencies. Nitrification is the name given to the process of oxidation by means of which complex nitrogenous compounds are converted into simple inorganic salts and in these forms they are readily assimilated by the plants. The importance of nitrification is readily seen when we consider that plants are unable to obtain their nitrogen directly from the complex nitrogenous compounds.

Warrington, Winogradsky and King, by an elaborate series of experiments, showed that this process of nitrification was brought about by certain bacteria. Wilfarth and Hellriegel in 1886 further demonstrated the fact that there were other bacteria which were capable of entering into a close combination with the roots of certain kinds of plants like beans, peas, clover and other legumes. These bacteria caused the development of nodules or tubercles on the roots of these plants and as a result of the partnership of the bacteria and the plant, the plant was endowed with the remarkable power of being able to obtain its nitrogen directly from the atmosphere and was, therefore, independent of the soil for its supply of this essential element. These nodule-producing organisms are frequently called the "nitrogen fixing" bacteria.

As is well known the Department of Agriculture has done most exhaustive work on these nitrogen fixing organisms, and has gone so far as to isolate them and distribute them to farmers so that they might be able to infect soil and seed with them. Not only is the crop increased by this process, but the nitrogenous content of the soil is augmented markedly on account of the stubble and roots left after the crop has been cut. These nodule-producing organisms are apparently only of value with the legumes referred to above, but there has been demonstrated a large class of organisms residing in the soil which can confer the power of obtaining their nitrogen from the atmosphere to non-leguminous plants.

With these facts in mind it follows that conditions which favor the growth of these various soil bacteria will likewise favor the fertility of the soil and the size and quality of the crop.

Experiments in various places have shown that by treating soil to certain weak disinfectants or by heating it, an increased fertility was brought about.

The explanation of these phenomena has apparently been found by Doctors Russell and Hutchinson who have studied carefully the chemistry and biology of soils under various kinds of antiseptic treatment and also treatment by heat. They find that immediately following the treatment there is a great fall in the number of bacteria in the soil, but that in a few days the number has increased so that it is greatly in excess of the normal numbers of untreated soil. Similarly, the ammonia in the soil has increased very greatly, and it was also found to be greatly in excess of the usual amount present.

An investigation into the causes of this remarkable state of affairs revealed the important fact that the incomplete sterilization or disinfection while only partially killing off the bacteria, actually practically destroyed all of the large group of organisms known as protozoa in the soil. Protozoa are unicellular animals of greater size and complexity than the bacteria and their presence in the soil has long been known. They are known to feed extensively on bac-

teria and consequently if the soil can be rid of their presence, it will be made a more favorable medium for the growth of the valuable bacteria, and thus lead to an increased amount of nitrogen in a form available for plant life.

It is hard to estimate the value of this discovery at the present time, but it is easy to see that it may be of very great significance.

Experiments are now being made to determine the practical methods for treating soils, so that the protozoa may be killed off and the bacterial growth favored.

If this is accomplished and the increased fertility of the soil assured, a great step in advance will have been made and another great triumph earned by the micro-biologists.

An excellent popular exposition of this research will be found in *Harper's Magazine* for October from the pen of A. D. Hall, F. R. S., director of the Rothamsted Experimental Station.

S. M. G.

NAVAL TESTS OF ELECTRIC COOKING APPARATUS

A REPORT has just been made by a board of officers appointed to investigate the comparative advantages of electric methods of cooking and the coal range for use on board warships. The tests were made with large quantities of material sufficient for a ship's company and the results are unusually interesting.

The range of experiments was very complete covering every operation required in cookery, the quantities being sufficient for one hundred and fifty men. A test showing the relative economy of operation was made on two ten-pound roasts of beef of the same shape,—one being cooked in the electric and the other in the coal-burning range. A thermometer was used to determine when the meat was roasted, the meat being removed from the oven when a temperature of fifty-five degrees C at the center of the roast was recorded. In this test, the beef roasted in the electric range was superior being more thoroughly cooked throughout. Following are the data in this test:—

	Electric	Coal
Quantity of beef . . .	10 lbs.	10 lbs.
Time necessary to obtain necessary temperature	50 min.	2 hrs. 25 min.
Time required for roasting	1 hr. 40 min.	2 hrs. 20 min.
Electricity consumed	7 kw. hrs.	41 pounds
Cost of electricity . .	.0525	.114285 (anthracite) .064944 (bituminous)

The above test shows that the electric range is somewhat less expensive to operate than a range using bituminous coal, based on the cost of electricity and coal on warships. Commissary stewards and ships' cooks who tried the range stated that the relative working capacity was fully 2 to 1. The board strongly recommended the installation of electric ranges on naval vessels.

THE TURBO-TRANSFORMER

IT is a well-known fact that the rate of revolution of a steam turbine at its greatest economy is much greater than the speed of rotation of a ship's propeller when most efficient, and when turbines have been used for marine propulsion it has been necessary to adopt some rate of speed between the two which results in a loss in efficiency.

Dr. H. Foettinger of Stettin, Germany, has devised a speed reducing gear which seems to do away with the difficulty above mentioned. In his device a steam turbine is made to drive water through a rotary pump the rotor of which is keyed to the shaft of the propeller. This hydraulic transmission device is called a transformer and in connection with this driving turbine constitutes what is known as a turbo-transformer. Doctor Foettinger claims an efficiency ranging from seventy to eighty-five per cent., as well as the advantage of easy reversibility and of the comparatively small reduction of efficiency when a ship is steaming at cruising speed. Simple arrangements have been devised for reversing the propeller without changing the direction of rotation of the actuating turbine.

One of Professor Jaggar's photographs—Convent Destroyed by the Earthquake

LECTURES IN DECEMBER

671ST MEETING
DECEMBER 13TH

Mr. Louis K. Rourke, the newly appointed Commissioner of Public Works of Boston, on "The Scientific Administration of Public Works," Huntington Hall, Tuesday evening, December 13th, at 8 o'clock. Mr. Rourke who was recently engineer in charge of constructing the largest of the three great divisions of the Panama Canal, has just accomplished a consolidation of the departments of the City of Boston having to do with engineering construction work, into a Department of Public Works. The new commissioner will draw a lesson from the effective organization at Panama and will show how this consolidation is a step in the direction of preparing for the greater engineering problems that the city may soon be called upon to face. The engineering administration of Boston touches every man and woman in the city and as Mr. Rourke has a pungent way of putting things, and as there will be an opportunity for discussion from the floor, the meeting will be an unusually interesting one.

672ND MEETING
DECEMBER 20TH

Professor Thomas A. Jaggar, Jr., in charge of the Department of Geology and Professor Charles M. Spofford, Hayward Professor of Civil Engineering at the Massachusetts Institute of Technology on "The Costa Rica Earthquake of 1910," Huntington Hall, Tuesday evening, December 20th, at 8 o'clock. Professor Jaggar and Professor Spofford made a special trip to Central America last summer to investigate the effects of the great earthquake at Cartago, May 4th, which caused widespread destruction of property and human life. Their purpose was to gain information on earthquake-resisting construction. Professor Spofford will discuss the effects of the earthquake on buildings and show how remarkably certain types of construction resisted even this violent shock. Professor Jaggar will describe the geological causes of the earthquake and will show some remarkable lantern slides. He will also describe the volcanic research work which the Institute of Technology is about to undertake on the edge of the crater of Kilauea, Hawaiian Islands, by the aid of the Whitney fund and gifts from friends in Honolulu and Boston.

MEMBERSHIP IN THE SOCIETY OF ARTS

The Society of Arts is contemporaneous with the Institute itself, having been established for forty-nine years. The 671st meeting of the society will be held on December 13th, as indicated elsewhere. The object of the society is to awaken and maintain interest in the practical advancement of the sciences and to aid in their development. During the winter, a series of lectures on scientific subjects will be given by speakers eminent in their professions, and discussions are invited from the floor.

These lectures form part of the educational work of the Institute of Technology, and will be held in Huntington Hall, Rogers Building, Boylston Street, directly opposite Hotel Brunswick. Persons interested in the aims of the society are eligible for membership. The yearly dues are three dollars, and members are entitled to reserved seats on presentation of membership ticket. These tickets are transferable. No seats will be reserved after 7.55 on the evening of the lecture. The publication of the society, Science Conspectus containing announcements of coming lectures and reports of those that have been given, will be sent regularly to members. There will be five numbers, December, January, February, March and April.

The society desires to benefit the greatest number possible and makes no charge for admission to the lectures. Every person for whom the program here presented has interest is cordially invited to attend. The work of the society has been and always will be of great value to the people and to the interests of Boston, and, as these are the only lectures of this character given in the city, it is hoped that they will attract many to lend their hearty interest and support and thus widen the influence and increase the efficiency of the society.

SEMI-CENTENNIAL OF THE SOCIETY OF ARTS

The Society of Arts received its charter April 10, 1861, and arrangements are now being made by the corporation of the Institute for commemorating this anniversary. The Society of Arts is coordinate with the Institute and at the time the society was founded, there were practically no books on engineering subjects printed in this country. The Society of Arts was one of the most important instruments for disseminating information in regard to the arts and sciences in the East, and on its

list of members were a large number of the substantial citizens of Boston. Dr. Oliver Wendell Holmes was on one of the early membership rolls which included a long list of the scientific investigators of that time.

The executive committee chosen to carry on the work of the society on the fiftieth anniversary of its birth is composed of Richard C. Maclaurin, president of the Institute of Technology, Theodore N. Vail, Elihu Thomson, James P. Munroe, Carroll W. Doten, Frederic H. Fay, and I. W. Litchfield. The increase in the membership of the Society of Arts last year was nearly twenty per cent.

THE AIM OF SCIENCE CONSPECTUS

Not many years ago a man might say, "I have taken all science to be my province," but the field has so widened during recent times that today it would not be possible for one mind to compass even a single branch of science. Almost every day there are new developments in special lines of research, any one of which may lead to fundamental discoveries, but, although these matters would be of general interest if they could be understood, their significance is often obscure, even to scientific workers in not dissimilar lines, because of the rapid changes in the conception of the relations of matter, because of the intricacy of ever-expanding special nomenclature and because of the almost daily progress in methods of delicate manipulation.

In enlarging the scope of the publication of the Society of Arts it is our aim to give, as far as we may be able, a general survey of the field of science and its applications in such a way that every article will have some educational value for every reader. We shall strive to describe the most important current developments in the field of scientific activity in terms within the understanding of the intelligent lay reader, and in general we shall confine these descriptions to reasonable limits, often to the extent of brevity. We shall not attempt to preserve a balance in the amount of material presented between various branches of science. Most of the articles will be original material from authorities in their special lines of investigation. The publication staff will, however, make digests and summaries of important articles as they may appear in current publications, and we shall not hesitate to reprint any articles which may be of particular value to our readers. The matter in Science Conspectus will not be printed simply because it is available, but will be carefully selected, and wherever possible will be amply illustrated.

ARTICLES TO APPEAR SOON

The *Bulletin* of the Society of Arts made many friends, but as there seems to be a desire for a publication of somewhat larger scope, it has been thought best to change the name to Science Conspectus, which will be published in December, January, February, March and April and sent to each member of the Society.

Some of the articles we are arranging for are: rubber substitutes and substitutes for rubber; this will be a general article covering the whole subject and showing how and to what an extent the use of rubber has been supplanted by other material; the present status of the atomic theory, which will brush up the lay reader's knowledge on the subject and show where the atomic theory now stands in view of the new discoveries in the line of radio-activity; rustless coating for iron, an article covering the general field and showing the relative commercial value of the various coverings for protection from oxidation; fourth dimension space, a short article explaining what the fourth dimension is; an article on non-Euclidean geometry, written for those who would be interested to know what this theory is. The Edison storage battery and an estimate of its future value; the practical results of

the pure food law, showing the tremendous amount of good that has resulted from this law and what it will eventually accomplish; an article on the Gnome motor for aëroplanes, and other aëroplane engines; an article on the field of the higher mathematics; earthquake resisting construction, the result of investigations by Professor Spofford in Costa Rica; advances in electro-chemistry, especially in regard to electro-metallurgy; curiosities of mathematics; chemistry of everyday life; research in aëronautics, as well as new and interesting developments connected with biology, sanitary engineering and preventive medicine.

INTERNAL COMBUSTION ENGINES FOR LARGE SHIPS.

It is reported that the Hamburg-American Line is building an 8,000-ton freight vessel, 400 feet long, which is to be equipped with two Diesel engines of 1,500 horse power each. It is expected that the power will be sufficient for a speed of eleven knots. The use of these engines will result in a great saving of space as the boilers and coal bunkers will be omitted. The space occupied by them will be available for the storage of cargo. The engine-room force will be greatly reduced, inasmuch as engineers and a few oilers are all that will be necessary.

The Diesel engine is an internal combustion engine, depending for ignition upon the compressing of the atmosphere in the cylinders to a point at which it is sufficiently heated to ignite the fuel, which is sprayed into the cylinder. The action under these circumstances is a burning of the fuel, rather than an explosion as in the ordinary gas engine. The fuel used is a petroleum residue, which is the cheapest grade of oil, and can easily be obtained on both sides of the Atlantic. One of the principal difficulties met has been the high pressure necessary. The Diesel engine has attained a thermal efficiency of upwards of thirty per cent., which is several times that which can be attained in a steam engine of the best type. There are incidental difficulties in the way of applying internal combustion engines, such as the installation of auxiliaries—steering gear, ammunition hoists for battleships, etc.—which are not easy of solution.

A stationary oil engine of the Diesel type has been built on the Continent which delivers 10,000 horse power, but it does not appear that any suitable clutch or other device for producing variations of speed, or for reversing, has yet been devised. The largest marine engines of this type hitherto built are of 500 horse power; so the great advance which it is proposed to make may be readily appreciated.

There has of late been considerable discussion with regard to the application of the Diesel engine to battleships; but the powers required are so large (between thirty and forty thousand horse power) as to make certain that in its present stage of development the Diesel engine is not adapted for use in powers of such magnitude. The manager of the firm in Great Britian which makes the Diesel engine has stated that he thinks we shall not see battleships propelled by internal combustion engines within the next ten years.

L. E. M.

ISOLATION OF METALLIC RADIUM

Mme. Curie and M. Debierne have succeeded in isolating what they believe to be pure metallic radium. The method employed was that of making 10 grams of mercury the cathode in a small cell containing a solution of about 1-10 of a gram of radium chloride ($RaCI^2$). They practised on barium chloride solutions until they could successfully carry out the operation with such small quantities. The amalgam thus formed was quickly transferred in an iron boat to a quartz tube and most of the mercury distilled off in a current of specially purified hydrogen gas at 270° C. The temperature was then gradually raised to 700° C. when no more

mercury could be found in the current of gas. The residue was a brilliant metallic substance which began to volatilize at this temperature. The vapor attacks quartz while the metal itself decomposes water rapidly and turns black in the air forming a compound with nitrogen. Measurements on the radioactivity are in progress and the results so far are quite in accord with what might be expected of the pure metal. Announcement of the isolation of radium and the methods employed will be found in *Comptes Rendus*, Vol. 151 (1910), page 523. E. B. S.

MALLET COMPOUND LOCOMOTIVE

THE most recent development in heavy freight locomotives is the Mallet articulated, compound locomotive, which consists essentially of two separate sets of wheels, with their frames and cylinders, which are coupled tandem by a flexible coupling. The boiler is much longer than in the ordinary locomotive, extending over both frames and sets of wheels. The tubes are lengthened out somewhat, but this does not use up all the extra boiler length. The remaining portion is utilized for a super-heater, also for a feed-water heater. The steam is first used in the pair of high-pressure cylinders on the rear engine, then passes to the low-pressure cylinders on the leading engine, and thence is exhausted up the stack.

In several cases these engines have been constructed from old engines of the consolidation or "prairie" type, by cutting off the forward portion, lengthening the boiler, putting in a new section consisting of a new front end for the boiler and a new set of wheels in front of the original set, and coupling them together.

These engines are very economical for heavy, slow freight service, but from an operating standpoint are not altogether successful for fast, high-grade merchandise. A few engines of this type have been used for passenger service on mountain roads. L. E. M.

MOTION PICTURES OF THE DIGESTIVE ORGANS

MR. J. CARVALLO of the Marey Institute, Paris, France, has recently succeeded in making cinematograph X-ray pictures showing the process of digestion both in warm and cold blooded animals. The value of these results is obvious as these moving pictures give us an actual view of the interior workings of the human body and for the first time physicians have been able to see an absolutely reliable reproduction of our organs in action.

Many attempts have been made to produce this result but they have failed because of the difficulty experienced in obtaining the Röntgen pictures with exposures lasting but a small fraction of a second; also because no suitable cinematographic apparatus was available for producing the pictures.

The animals under test were fed with an alimentary paste or with their usual food mixed with a basis of bismuth nitrate. The results of these pictures have been checked by special investigations showing that the pictures are true photographs of the actual movements of the organs. Mr. Carvallo has produced X-ray pictures which are said to show the digestive process in the most differently constituted animals.

THE SUBMARINE AS A SEA-GOING VESSEL

THE tests made on the submarine *Salmon* during the summer have placed submarines on an entirely new footing. Hitherto these vessels have been looked upon as useful only to assist in defending harbors and their value has been mainly due to their "moral effect." The record breaking cruise of the *Salmon* was from Quincy, Mass., to Bermuda and return, covering 1,514 miles, a distance never before attempted by a submarine. During the trip very heavy weather was experienced and for three quarters of the time of the outgoing run, the vessel proceeded under

one engine. The boat was comfortable throughout the trip although she carried passengers in excess of her crew. The ventilation of the boat was satisfactory.

The *Salmon* is 134 1-2 feet long by 15 feet in diameter. On her official surface speed trials she made 13.25 knots. In diving, water is admitted to the ballast tanks and then a slight depression of the diving rudder causes the boat to dive at an angle of inclination of from one to two and one half degrees until the required depth of fifteen feet is reached when the hull is submerged and nothing but the periscopes are visible. The *Salmon* has effected a quick dive at full speed of 13.25 knots in three minutes and twenty-two seconds.

AERONAUTICS IN 1910.

The year 1910 has been an important one in the field of aëronautics especially in America. There has been comparatively little advance in the dirigible balloon, the most notable event being the flight of Wellman, which added nothing of any value to the art. As a matter of fact, Wellman's device was not a dirigible balloon as it was tied to a float. A small boat might have been used as a drag instead of the wooden blocks at the end of the so-called equilibrator, and indeed, it is a question whether he would not have made a better showing if he had used a boat having a motor propelled screw, attached to the end of the equilibrator, the motor being operated by the engines in the balloon.

The art of building and manipulating aëroplanes was greatly advanced during the year and it is safe to say that the lessons of this prolific period will have a marked effect in greatly widening the scope of the art during the year to come. The culminating event of the season was the Belmont Park meet which was full of notable achievements of the world's best aviators. This meet showed beyond much question that the speed limit of aëroplanes has been practically reached. This was shown by the injuries to the 100 H. P. Bléroits of Grahame-White and LeBlanc, and the 8-cylinder Wright. These racing machines had small wing surface and for this reason it was hard to start them in flight and still more difficult to alight safely. Higher speeds would require still smaller wing surface making the process of alighting, which would have to be done at high speed, extremely dangerous.

The speed trials were the most sensational events of the meet, but no one who has seen the Wright bi-planes in the air can help being impressed with their steadiness and the security they seem to offer. In the development of this type of air craft, which can apparently be manipulated with almost the ease of a sail boat, there seems to be something really substantial on which to build for the future. It is likely that the bi-plane will still further be developed on the lines of stability and ease of manipulation during the coming year.

Two important features in which America is markedly behind Europe, are the engines and thoroughness in construction. So much interest is manifested in the Gnome engine that it will be described in a future number of SCIENCE CONSPECTUS.

THE LARGEST VESSEL IN THE WORLD.

The Cunard Steamship Company is about to build an ocean liner 885 feet long with a total displacement of 45,000 tons. She is expected to make a speed of 23 knots and will carry 37,090 passengers. The vessel will be propelled by steam turbines and will be provided with a theatre, swimming pool and printing plant from which will be issued a daily newspaper. She will cost $10,000,000.

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THE EARTHQUAKE IN COSTA RICA

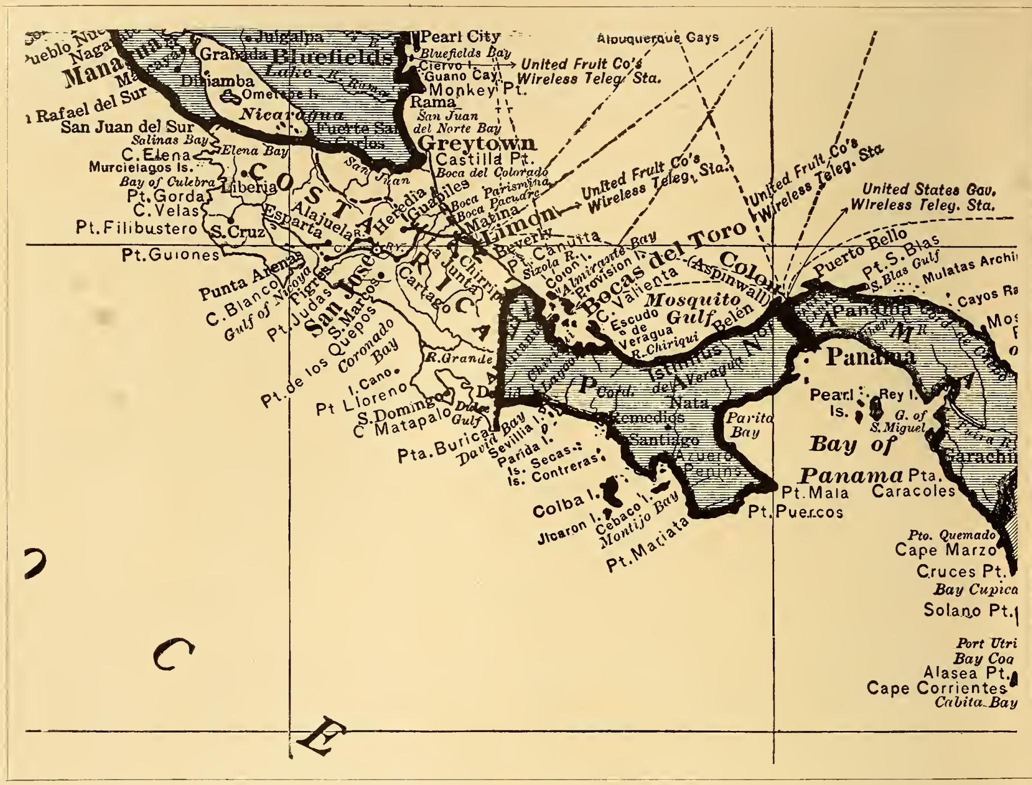
TECHNOLOGY EXPEDITION STUDIES VOLCANIC AND EARTHQUAKE CONDITIONS IN CENTRAL AMERICA—LECTURE BEFORE THE SOCIETY OF ARTS, DECEMBER 20TH

BY T. A. JAGGAR, JR.

By invitation of the United Fruit Company, Professor Spofford and the writer left New Orleans, May 24th, arriving in Limon, Costa Rica, May 30th, where we were hospitably entertained by officials of the fruit company. The next day the party traveled by railway to San José, the capital, passing Cartago on the way. The itinerary of the expedition involved a stay in the vicinity of Cartago among the high volcanoes of Costa Rica from May 31st to June 10th. On June 11th we returned northward in the Caribbean Sea by way of the steamer of the United Fruit Company to Barrios, Guatemala, arriving June 13th. We then proceeded by rail to Guatemala City among the high plateaus and volcanoes of the interior of Central America and remained there until June 19th. On that date we proceeded to the Pacific coast of Guatemala and took a Pacific mail steamer for Panama which was reached June 27th. We remained in the canal zone, most hospitably cared for by the officials of the canal, until July 1st, when we sailed from Colon on the Atlantic side for Kingston, Jamaica, arriving there July 3d. We stayed long enough in Kingston to see the remarkable work which is there being done by the government in enforcing earthquake - proof construction, were entertained by the official inspector of buildings, Mr. Arthur Herschel, and then returned directly to Boston by sea, arriving home July 11th.

The objects of this schedule were: First, to study the ruins of Cartago and the volcanoes of Costa Rica; second, to examine the earthquake and volcano-disaster records of Guatemala and learn how the methods of construction there compare with those of Costa Rica; third, to see as much as possible of the remainder of Central America and Jamaica with a view to the earthquake question.

The harbor of Limon on the Caribbean coast of Costa Rica is situated within a broad coastal plain which extends from Costa Rica northward through Nicaragua. The San Juan river in Nicaragua, site of the formerly proposed canal, flows across this plain. The plain is an upraised Caribbean sea-bottom which has been slowly rising for several geologic epochs. Back of this plain to the southwest lies the mountain wall of Costa Rica, along the border of which the ancient Caribbean coast formerly lay. This mountain wall is made up of several ranges of peaks consisting partly



Map of Southern Part of Central America

of old rocks such as granite, and partly of volcanic ejecta, especially in the northern part. The mountain line trends northwest and southeast, and deep valleys have been trenched within it, draining off its abundant rainfall toward the Atlantic on the one side, and the Pacific on the other. Cartago and San José, at elevations between 4,000 and 5,000 feet above sea-level, lie in broad upland basins in the heart of this mountain district, where the climate is that of a perpetual springtime and where crops of the temperate zone are raised. From Cartago northward the mountains are gigantic volcanoes rising to heights of from 8,000 to 11,000 feet and showing various stages of dying activity. The great volcanoes lie in lines, and the lines are the surface expression of underlying deep rifts in the crust of the earth which for ages have given vent to sand and rock fragments and liquid lavas so as to build huge cones and craters. The fact that Cartago lies just on the southeastern terminus of these volcanic rifts is of interest to students of the earthquakes there. It is no new thing for Cartago to suffer by earthquake. In 1841 it was totally destroyed, and on May 4, 1910, its destruction was repeated.

Thanks to the interest of President Jiménez in our work, and the untiring devotion and energy of Don Anastasio Alfaro, director of the museum at San José, we were able to send out circulars through the government to officials throughout Costa Rica, asking for answers to certain definite questions designed to determine the intensity of the earthquake in different places. The answers to these circulars have made it possible to map the earthquake by zones, numbered according to what is known as the Rossi-Forel scale of earthquake intensities. The numbers are graded from one to ten, No. 1 being a shock so weak that it is perceived only by instru-

Limon, Costa Rica, looking east

ments, and No. 10 so strong that it overturns rocks, makes fissures in the ground, and throws down even wooden buildings. The shock in Costa Rica was nowhere stronger than No. 9, which was the intensity at Cartago, where brick and adobe were thrown down, and some wooden buildings wrenched out of shape. The distribution of intensities in Costa Rica indicates an even dying away of the force of the shock on the Caribbean side as the earth-wave traversed the coastal plain, like the ripples in a pool of water disturbed by the plash of a pebble. On the Pacific side, however, where the mountain ranges are, and particularly northwestward along the repeated step-like volcano lines the wave was obstructed and moved through the ground, from Cartago as a center, more irregularly. The great volcano Irazu, twelve miles north of Cartago, appears to lie on the corner of an immense block of the earth's crust, and this corner was the earthquake center. Around Irazu and three neighboring volcanoes the disaster focussed. The earth-waves lost intensity about thirty miles to the westward, revived about a second group of volcanoes still farther west, but with greatly diminished force, and faintly revived again about a third group of volcanoes fifty miles farther in a northwesterly direction. These facts can be interpreted possibly as meaning that all of these volcanoes lie along a zigzag fracture line with Irazu near the southeastern end of the fracture. Sudden release of some accumulating crustal stress at the Irazu corner made a terrible jar in that immediate vicinity, and similar jars on a diminishing scale took place at other corners northwestward. Cartago and Paraiso received the brunt of the shock. The direction of motion of objects displaced in these and other places shows when platted on a map a marked accordance with the volcano lines.

Santa Maria Volcano, Guatemala

During our visit, we found time to climb Irazu and Poas volcanoes, and pictures of their craters are here reproduced. Irazu showed no volcanic activity sympathetic with the earthquake, but Poas broke into eruption on January 25, 1910, scattering ashes and mud

Crater of Poas Volcano, Costa Rica

over the country. This eruption was the first sign of movement on the volcanic fracture. It was followed April 13th by a strong earthquake, the first of its kind in some years, which damaged San José more severely than Cartago. The shock came shortly after midnight, and for two weeks thereafter rich and poor alike became refugees from their masonry dwellings and camped in open shacks and tents. During this period there were innumerable after-shocks, and the earth was clearly in a state of great unrest. The center of the April 13th shock was somewhere to the southeast of San José and to the west of Cartago. On May 4th about 7 o'clock in the evening, the great earthquake came which demolished Cartago. It was compounded of movements at first vertical, then mostly from the east, so that walls and fence-posts and statues and monuments were displaced, or fell over, toward the east. At Paraiso, two or three miles east of Cartago, the later movement was more to the northward. As there is one volcanic line connecting the volcanoes Irazu and Turrialba which trends northeast and another from Irazu northwestward, and these two cities lie just at the corner, there is probably much significance in the observed directions of motion above mentioned.

The time of the earthquake was 7.31 P. M. by our eastern standard time, and its duration 16 seconds. A simple type of seismograph consisting of an inverted pendulum which writes with a quill on a smoked plate, is maintained at the Meteorological Observatory in San José. I have reproduced a copy of the earth autograph which was made by this instrument April 13th. As the waves

Crater of Irazu, Costa Rica

spread out throughout Costa Rica, objects were displaced along lines chiefly radial away from the center, or

Seismogram made at Observatory, S. José, April 13th, 1910

in directions at right angles to the trend of the great rift, that is, in western Costa Rica the directions recorded are mostly toward the southwest, and in eastern Costa Rica toward the northeast. Almost all the observers heard a subterranean noise which was reported variously as sounding like the passage of a train through a tunnel, or like the rush of a great stream of water, or like a mighty wind, or a prolonged thunderclap. The Spanish name for these earthquake rumblings is *retumbos*, and these *retumbos* are familiar happenings in central Costa Rica. A curious coincidence immediately after the earthquake was an unusually bright meteor observed by many persons.

There were no conspicuous geological effects, such as rents in the ground or tremendous landslides. This fact helps to corroborate the supposition that the main rift in the ground which was responsible for these quakes is the huge fracture which underlies the volcanoes, but is invisible at the surface. In marked contrast to what happened in San Francisco in 1906, it is noteworthy that neither

Panorama from the Summit of Irazu looking W.N.W.

View of the Ruins of Cartago looking West

the railway nor sewers nor the water conduits of Cartago were injured or twisted. No very important changes in the drainage were noticed, though some warm springs were said to be hotter than usual, and some springs revived and others ceased running at about the time of the disaster. The officials of the United Fruit Company told us that the rainfall on the Atlantic slope of Costa Rica was excessive during the four months which preceded the earthquake.

I have reproduced three pictures illustrating the volcanic lands of Guatemala which are of interest by way of comparison with Costa Rica. One of these shows the ancient capital, Antigua, which lies very near to the great Fujiyama of Guatemala, the volcano Agua, one of the most beautiful cones in the world. Antigua was destroyed by earthquake in 1773, and the capital was thereafter officially removed to the site of Guatemala City. This site is believed to be safer, and is somewhat more remote from the line of Guatemalan volcanoes. In Guatemala, as in Costa Rica, the volcanoes lie in very marked lines and in 1902 Guatemala learned that cones which are supposedly extinct may suddenly awake with dire results. The volcano, Santa Maria, 12,000 feet high, suddenly became active October 24, 1902, and the whole side of the mountain was blown out, producing days and nights of darkness over hundreds of square miles, while dense clouds of ash and stones fell upon the country, and destroyed villages and coffee plantations. The eruption was one of the greatest in history, but the world at that time was weary of hearing about vol-

Refugees Camping in the Open

canoes, owing to the destruction of Saint Pierre which happened the preceding spring. The Santa Maria explosion was many times greater than the eruption of Mount Pelée, but only 400 or 500 people were killed, as there was no great city in the line of fire.

In conclusion it may interest the readers of this magazine to know that the Department of Geology of the Institute was enriched in July, 1910, by a gift of $25,000 for geophysical research from the estate of Edward and Caroline Rogers Whitney. It is specified in the deed of gift that the work carried out with the income of this endowment shall have a bearing on the protection of human life and property. The first work which will be done by the Institute under this endowment will be in that ideal field of seismo-volcanic research, the territory of Hawaii. For some years past, Institute geologists have been interested in this field, as the crater of Kilauea is a place of practically continuous activity of boiling lava, which there has great liquidity, and rarely explodes in any dangerous way. The Volcano House on the edge of this crater is visited continually by tourists and the climate is cool and invigorating. A day's journey away by steamer is Honolulu, a center of wealth and enterprise. The American residents in the Islands are much interested in the scientific study of their volcanoes, and have offered to subscribe a large sum of money, and give land and every assistance to the Institute if we, in addition to the resources of the Whitney Fund, will send a salaried officer to reside at the proposed volcano experiment station and become its superintendent. The Carnegie Institution of Washington and the United States Weather Bureau have agreed to coöperate with the work of this station, and an officer from the Geological Department will, it is hoped, soon go to Hawaii and start the work. In order to benefit by the subscription of the Honolulu business men, which amounts to $5,000 per annum for five

Ruins of Antigua, the old capital of Guatemala, destroyed by Earthquake in 1773

years, all that is now needed is a like subscription from Bostonians of at least $2,000 per annum for five years, to pay the salary of the superintendent whom we shall send out.

It is to be hoped that this money can be raised. The Institute has an opportunity in this Hawaiian field to investigate the most fundamental processes which govern the earth that we live upon. These investigations have a

Agua Volcano, Guatemala

humane object. Studies of the temperature and viscosity of liquid lava, of volcanic gases, of local earthquakes, of underground sounds, of the relation of all these things to the great tidal stresses which are incessantly passing through the earth, may be made in Hawaii, using those wonderful volcanic orifices as a scientific laboratory, the like of which exists nowhere else on earth. It is appropriate that a great engineering school should deal with fundamental studies of the earth and its processes. Engineers are forever struggling with the earth and its processes when they build houses, culverts, dams and bridges. San Francisco and Messina have taught us the lesson.

REMARKABLE PROPERTIES OF "BAKELITE"

The new substance called "Bakelite" which is now being introduced into the arts offers the advantages of hard rubber, Japanese lacquer and celluloid and in many respects is superior to these substances. It is not a compound or mixture of rubber or resinous materials, but is a well-defined chemical substance made from carbolic acid and formaldehyde, and was invented by Dr. L. H. Baekeland of Yonkers, N. Y., the inventor of "Velox" and other gaslight photographic papers. The synthesis of "Bakelite" is analagous to the operation that goes on in the Japanese lacquer tree in producing lacquer. This new artificial material will to some extent take the place of lacquer and can be made at a reasonable price.

The most peculiar physical characteristic of "Bakelite" is, that it appears in three forms, each of which has very different properties and can be used for different purposes. The first form known as "A" may be in a liquid, pasty, or solid condition; it is soluble in alcohol, acetone or caustic soda and behaves as a true resin. When heated to a high temperature, it changes into "Bakelite B" which will not dissolve in the solvents mentioned above, although phenol or acetone may soften it or swell it. It is infusible but softens slightly under the influence of heat. "C" is the final product resulting from the heating of "B." It is no longer a resin although physically it resembles amber. It has neither taste nor odor. It is insoluble in all solvents and can withstand strong chemicals, oil, or water, steam, etc. It is stronger and harder than celluloid or hard rubber, but is not as flexible. It is burned with great difficulty. It has many important uses. The chemical name for "Bakelite" is oxybenzylmethylenglycolanhydride.

EARTHQUAKE ENGINEERING

CONCLUSIONS REACHED AFTER AN INVESTIGATION OF THE COSTA RICA DISASTER — LECTURE BEFORE THE SOCIETY OF ARTS, DECEMBER 20TH

BY CHARLES M. SPOFFORD

THE tremendous loss of life and property in the last decade by earthquake shock and volcanic eruption has strikingly demonstrated that civilization has still much to fear from the forces of nature; and has shown the scientist that in the study of these phenomena there exists a fertile field for work in the interests of humanity. The earthquake problem, as it presents itself to the scientific man, has two distinct phases—prediction and prevention—prediction of the probable location and time of occurrence, and prevention of loss of life and property during occurrence. The solution of the former problem must be acccomplished by the geologist, with the assistance of the physicist, the chemist, and possibly the astronomer; of the latter, by the engineer. The crystallization of the results obtained by the geologist and the engineer requires furthermore the coöperation of the lawmaker and of the capitalist, in order that they may be made of advantage to the world at large.

It is the purpose of this paper to present the subject from the standpoint of the engineer—to state the questions involved— and to present such conclusions as it may seem justifiable to draw from the results of the earthquake of last May, which destroyed, with great loss of life and property, the city of Cartago, Costa Rica.

Human action is governed by many conflicting influences. A study of history shows that the mere fact that a city has been destroyed by natural phenomena in times past, and may reasonably expect to be so destroyed again, is insufficient to prevent its rebuilding, provided the natural conditions which caused its original development are not destroyed. It is, therefore, essential that special precautions be taken at such cities as are located at the danger spots of the world, to prevent future destruction. In Galveston and Holland sea walls and dykes are necessary, but in Kingston, Valparaiso, San Francisco, Messina and Cartago special forms of constuction will alone accomplish the result.

The engineering question, however, is not merely that of determining an earthquake-resisting type of construction, since this is a problem which in itself presents no serious difficulty. The ocean traveler who rides with safety over great seas in the gigantic *Mauretania* travels in a structure which would be as safe in time of earthquake as in time of storm. The steel-frame building of lower Broadway, founded on solid rock and riveted securely together, would be equally safe if walls, floors and partitions were to be made of iron plates as in the ship. As in other engineering questions, economy must also play a leading part in the solution. It is necessary not only to build securely, but also with due regard to economy of construction, to the customs and tastes of the people, and to the natural resources of the country. It is, however, not the purpose of this paper to enter upon a discussion of questions such as these, which can be solved only for specific cases, for which definite data are available. Its object is rather to illustrate the effect of earthquakes upon different types of buildings, and to point out such general conclusions as may seem justifiable from the data thus obtained, in the hope that thereby some assistance may be afforded to him who may have to

Ruins of Adobe buildings in the foreground

deal with the specific problem of design in earthquake-afflicted countries. From this viewpoint the following description of the earthquake of May 4th last, which resulted in the entire destruction of Cartago, should be interpreted:

The city of Cartago lies in the central portion of Costa Rica, midway between the Atlantic and Pacific oceans, and two or three miles east of the continental divide Its distance from either coast is about ninety miles, and it is in direct communication with the important harbor of Port Limon on the Atlantic coast by the Northern Railway of Costa Rica, a line controlled by the United Fruit Company of Boston, through whose courtesy Professor Jaggar and I were able to visit the city. Its elevation above the sea level is 4,700 feet, and although it lies but ten degrees above the equator, its climate is cool and bracing and it is comparatively free from tropical diseases. Its population before the earthquake consisted of from 8,000 to 10,000 people. It was visited to a considerable extent by tourists, and in recent years by Americans from the Canal Zone, who used it as a ready means of escape from the humidity and enervating climate of the Isthmus.

The ordinary forms of construction employed in the city may be divided into four different classes, which, arranged in the order of their frequency, are as follows: adobe, brick and stone masonry, *bahareque,* wooden-frame buildings. If the above arrangement were to be reversed, it would show the relative resistance of the different types to the shock,—a striking commentary upon the wisdom of builders and owners.

Nearly all of these buildings were roofed with heavy red Spanish tiles,

Ruins of Carmen Church, Cartago

which, while offering protection against sun and rain and adding a touch of picturesque coloring to the city, formed a deadly menace in case of earthquake, and were doubtless responsible for a very considerable proportion of the deaths on May 4th.

Of these different forms of construction two are unknown in New England,—the adobe and the *bahareque*. The former, however, is commonly used in certain portions of the United States and is doubtless familiar to many of you. It consists merely of sun-dried mud bricks. To obtain the best bricks, straw should be mixed with the mud, but in much of the Cartago adobe the straw was omitted. As heavy tile roofs cannot be supported by walls of this weak material, wooden uprights are used to support the roof beams or rafters, these uprights being nothing but rough posts inserted a short distance into the ground. The walls of these adobe buildings are sometimes several feet thick.

Bahareque is the name given to a type of building consisting of a crude wooden framework in which the uprights are held together by horizontal ribs of native cane placed several inches apart. The walls of such buildings are formed, in the case of plain *bahareque*, of a plaster of adobe mud, and in the *bahareque de ladrillo* of bricks. The better type of the plain *bahareque* buildings are constructed by driving into the ground at intervals of about three feet posts of a very hard and long-lived wood, called *guachipelin*, which is commonly reported to have a life of one hundred years under these conditions. Upon these, posts of an inferior wood

Parochial Church, built of cut stone

are erected, the two sets of posts being thoroughly spliced above the ground level. These latter posts are braced by diagonals, thus forming the framework of the building itself. Upon both the inside and the outside of this framework are nailed strips of one of the native canes, laid horizontally at intervals of six inches or thereabouts. These strips extend completely around the building, holding the verticals firmly together and forming a sort of basketwork frame or wattle. The mud to form the walls is then pressed by hand between and around the canes. Such buildings are of a pleasing appearance which the description of their construction would not indicate.

That there were so few wooden buildings in such a sparsely settled country as Costa Rica deserves brief comment. The reason for this is not lack of good timber, since portions of the country are heavily timbered and much of the timber is of excellent quality. It can probably be attributed in part to the influence of Spanish architecture, with its almost exclusive use of masonry, and partly to the difficulties of lumbering in a mountainous country where snow and ice never occur to make trasportation easy.

Adobe:—The adobe buildings were very generally destroyed, the mud walls disintegrating under the shock and the heavy roofs falling. The fact that this material has no resistance to tension makes it practically worthless to resist severe sidewise vibration and the resulting diagonal tension accompanying the shearing forces. Moreover, its crushing strength and elasticity are so low that it can offer little or no resistance to the sudden upward blow of an earth wave. It would seem that the strength of buildings of this material depends but little upon the thickness of the walls, that is, assuming that the walls be made of reasonable thickness and be not merely mounds of earth.

Brick and stone masonry:—These buildings are grouped together, as there was no marked difference in the resistance they offered to the shock. As a general thing it may be said that the

Señor Troyo's brick house before the earthquake

Señor Troyo's house after the earthquake

material used was not of the best quality, and that the workmanship was not especially good. The mortar was invariably of lime, Portland cement being practically prohibited by its price. The stone masonry was usually a lime rubble made by depositing lime mortar in wooden forms and then throwing stones into this matrix. While in general the buildings in Cartago were but one story high (that being a concession to the recognition of the city's dangerous location), the brick and stone buildings were usually of greater height, their builders apparently feeling that the supposed additional strength of the material would more than offset the greater vibration due to increased height. The severe damage which stone buildings suffered is clearly shown in the cuts. It should be observed that mere thickness of wall was of no apparent assistance in resisting the shock, and that failure was by no means restricted to the highest portions of these buildings. There was one church in the process of construction,—the parochial church,—in which cut stones were used. The walls were practically finished, although the roof was not in place. This structure resisted the earthquake far better than the poorer buildings previously described, and would doubtless have done still better had the walls been tied together by a strong roof. Nevertheless, it was left in such a condition as to require partial, if not entire, rebuilding. This building is particularly interesting to the geologist because it was the only stone building in the city which could be compared with first-class stone buildings in this country.

Brick buildings suffered equally with stone. The two-story dwelling occupied by the Guatemalan representative to the Peace Court resembled perhaps more closely the brick dwelling houses of this city than any other brick building in Cartago. This was completely destroyed. There is no reason to expect that our houses would prove materially better, should Boston ever be subjected to an equally severe shock. In fact, the Back Bay district, with its soft, filled land, is doubtless more susceptible to destruction under a similar shock than was Cartago.

The most widely known building in the city was the recently constructed Peace Palace,—designed and constructed by native architects and builders from funds given by Mr. Andrew Carnegie of New York. This also was a brick building, but had in its walls steel verticals to which the light steel roof trusses were apparently anchored. These verticals were small and flimsy; whether they were expected to reinforce the walls, and thereby make them strong against vibration, I cannot say. The fact remains that the building was badly ruined; and it is the speaker's opinion that its destruction was aided by the lever-like action of these upright columns when set in motion by the earth waves.

Bahareque buildings:—These resisted the shock remarkably well, and are probably as nearly proof against total destruction as any form of inexpensive, non-combustible building. As previously stated, diagonals should be used to give rigidity to the framework. If these are omitted, the building may list bodily.

Wooden frame buildings:—As already said, there were but few of these in Cartago or vicinity. The two Cartago railroad stations and the station at Paraiso (a nearby village, where the destruction was as complete as in Cartago itself) form the sum total of such buildings so far as the speaker was able to determine. Not one of these stations was appreciably injured structurally, although minor damages occurred.

One of the most interesting buildings in the entire city was a dwelling house occupied by Señor Peña. The upper story of this house consisted of a wooden framework, with walls and partitions of metal laths covered with lime mortar and plaster. The lower story of this same building was of brickwork, which was considerably damaged. The upper story, however, remained entirely uninjured, even the wallpaper showing no sign of disturbance. That this immunity from damage may be attributed entirely to the resistance of the wooden framework and its covering of metal and mortar is evident, since the damage to the lower story shows that the building could by no chance have been located at a nodal point. Indeed, it is the speaker's belief that the strength of the wooden framework was largely responsible for the comparatively little damage to the brick walls.

Peña House, Cartago

While many more examples of each type of building might be shown, the speaker feels that he has given enough to confirm the correctness of the following conclusions:

1st. That no building constructed entirely of material with low tensile resistance or little elasticity is safe against severe shock. This applies to adobe, ordinary brickwork laid in lime mortar, and lime mortar rubble.

2d. That buildings of first-class cut stone masonry laid in lime mortar, even when of low height, are subject to consid-

Remains of Carnegie Peace Palace, Cartago.

erable damage by severe shocks, although they may not be entirely destroyed.

3d. That, in general, elasticity, continuity and lightness of structure are of more importance than thickness of walls or low height.

4th. That wooden-frame buildings of moderate height, with walls and partitions formed of metal laths or expanded metal covered with lime plaster, will resist with little or no damage very severe shocks, provided no earth fissure occurs. Such buildings should have continuous or thoroughly spliced vertical and horizontal members, which should be well tied together at joints; roof rafters should be securely held at ends by continuous horizontal ties, and floor posts firmly fastened to the vertical members.

5th. That projecting balconies and cornices, and heavy tile roofs are dangerous in the extreme. The latter should be prohibited by law, and the former used only when constructed in the strongest manner and under rigid inspection.

It is to be regretted that no reinforced concrete or steel-frame buildings existed in Cartago, and that it is therefore impossible to present conclusions concerning their behavior. There seems little doubt, in view of the experience in San Francisco, that steel-frame buildings properly built and braced would have resisted this earthquake as well as, if not better than, wooden-frame buildings.

No evidence can be obtained from this earthquake as to whether or not reinforced concrete is a suitable material for earthquake-resisting structures, since none of it existed in Cartago or vicinity. Concrete itself has little or no tensile

resistance, which must be furnished entirely by the steel reinforcement. This and its weight are against it. The English government, in the reconstuction of Kingston, Jamaica, has shown its faith in this material by using it exclusively in its new government buildings; and it is also being largely used by private interests in the same city. It is the speaker's belief that reinforced concrete, when properly constructed under rigid supervision by competent engineers, should resist earthquake shock such as this without total destruction, although it might be badly cracked and difficult to repair. The experiment at Kingston is an interesting one, and the effects of the next severe earthquake upon its numerous reinforced concrete buildings is a subject which should be studied with keen interest by all engineers.

THE INSTITUTE AND PURE SCIENCE

The biographical directory of *American Men of Science*, edited by Professor Cattell of Columbia University in 1903 has just been reissued and an interesting comparative study of the changes from 1903 to 1910 has been published by the editor. Some of the facts brought out are of particular interest to Technology men.

It should be noted at the outset that the statistics given relate wholly to the advancement of science, so that our strong engineering departments are not represented. Again, the comparison of institutions is to a large extent the comparison of graduate departments since it is these which bear the closest relation to the advancement of science. Under these conditions it is, therefore, particularly gratifying to find that in chemistry the Institute "easily leads" all the colleges and universities of the country, and that in the pure science departments of physics and mathematics, where graduate work is not yet developed, it stands sixth and ninth, respectively.

The institutions which have made, since 1903, the largest gains in the total number of their leading scientific men are: Harvard, 14; Wisconsin, 12; Chicago, 10; Yale, 8; The Institute of Technology and the Carnegie Institution, 7 each. The total present numbers are: Harvard, 79½; Columbia, 48; Chicago, 47½; Yale, 38; Cornell, 35; Johns Hopkins, 33½; Wisconsin, 30; M. I. T., 25, etc., fractions representing part-time service. The only other technological institution having three or more is Worcester, with just that number.

In a comparison with certain other educational factors, it appears that the Institute has one of the leading scientific men for every ten members of its instructing staff; Harvard, one in eight; Yale, one in eleven, etc.

In comparison of the number of scientific leaders with the value of its real estate, the Institute stands first, with one for each $53,000 of property. Harvard has one for each $138,000, while certain institutions near the other end of the list are credited with more than $600,000 for each scientific leader.

In the proportion of scientific men to current income the Institute is again near the head of the list.

There are six more graduates of the Institute in the leading thousand scientific men now than in 1903.—*Technology Review.*

SARGASSO SEA A MYTH

A Norwegian expedition sent to search for the Sargasso Sea has returned with the report that there is no such sea. The expedition found seaweed, but in no such quantities as have been reported for the last few centuries. The seaweed collects at the point of anti-cyclone which generally exists over the North Atlantic. The quantity of seaweed is largest during the third quarter of the year. These algæ float on the surface for five or six months, after which they lose buoyancy and sink to the bottom.

THE ULTIMATE STRUCTURE OF THINGS

A BRIEF EXPOSITION OF MODERN IDEAS CONCERNING THE CONSTITUTION OF MATTER, IN THE LIGHT OF RECENT DISCOVERY

BY D. F. COMSTOCK

Introductory.

The purpose of this paper and those which follow is to give a very brief outline of modern ideas respecting the ultimate constitution of the things we see around us. Since most people not scientists are unwilling to give much *sustained* attention to any scientific exposition, it has been thought best to run the risk of being somewhat disjointed and make each paragraph more of a detached unit than is usually done. This reduces the amount of sustained attention necessary on the part of the reader, but it unavoidably involves some repetition and is, of course, highly unconventional. When everything is considered, however, such an innovation will, it is believed, conduce to clearness and that after all is what we most desire.

During the last two decades there has been a very great advance in our knowledge of the ultimate constitution of matter. Since 1890 a veritable wonderland has been opened up in the field of fundamental physics. The old ideas which prompted the contemptuous phrase "gross matter" are hopelessly inadequate to represent the marvelous complexity and delicacy of structure which have since been revealed. The end is, of course, not yet, but throughout all this advance there has been singularly little in former ideas which had to be considered totally wrong. They were right as far as they went, but were hopelessly, pitifully inadequate, and so it probably is with our present ideas respecting the structure of things; they will doubtless appear crude in the light of future knowledge but they are probably right as far as they go, and hence are thoroughly worthy of our attention.

The reader's pardon is asked for beginning, as we do, without assuming any knowledge of the subject. It is easier for one reader to skip than for another to invent explanations, a fact not often realized in scientific writing.

THE ULTIMATE REALITIES.

All bodies as we know them are complex structures composed of small particles called *atoms* together with still smaller particles known as *electrons*. If, therefore, we were familiar with all the laws of action of atoms and electrons we would understand completely all the physical phenomena in nature. Fundamental physics might, therefore, be called the science of atomic etiquette and any physical science which you choose is but a chapter in the rule book. Indeed "The Nature and Action of Atoms and Electrons" would not have been a bad title for the present article.

ATOMS.

Size.—Atoms are minute particles each about one-three-hundred-millionth of an inch in diameter. If the earth were made up of base balls it would be a fair model of a drop of water made up of atoms.

Note:—Many scientific men, familiar as they are with the vast number of almost hopelessly stubborn problems which must be solved before our knowledge of the structure of matter will be anything like complete, will probably object to the "smugness" of the following presentation. It represents, however, essentially what they believe and is the only *form* in which the subject can be made popularly intelligible. —The Author.

The most powerful microscope known, used under the best conditions, would enable us to see an object which was two hundred molecules in width.

Shape.—Not much is known as regards the exact shape of the atoms, but apparently they are not very far from spherical.

Different Kinds.—There are now known nearly one hundred different kinds of atoms, that is, different species. The individual atoms in each species are, however, exactly alike. Atoms of different kinds differ in size and still more in weight. An atom of the heaviest kind known is about 240 times as heavy as one of the lightest kind. The diameter of the former is, however, only about two and one-half times as great as that of the latter.

The different species of atoms have quite different properties, and this difference in property is what gives variety to the world as we see it.

TENDENCY TO FORM GROUPS (MOLECULES).

Atoms tend to form groups known as molecules. The atoms in a molecule stick together very tightly indeed and some molecules can be broken up only with the greatest difficulty. These groups have a definite individuality and unless acted on from the outside they are in general permanent. The same atoms may be grouped into quite different molecules just as the same bricks may be used to build a church or a jail, or the same letters used to form altogether different words. The individuality of a molecule is akin to the individuality of a word. A word, though consisting solely of letters, has a definite unity of its own. A molecule made up of atoms is just as definite an aggregate. In Figures 4 and 5 water molecules, each consisting of two hydrogen atoms and one oxygen atom, are seen in the closely crowded state known as liquid and in the more dispersed state known as gaseous (steam).

Elements and Compounds.—When the atoms making up the molecules of a substance are all alike, that is, belong to the same species, then the substance is called an "element." An element, therefore, is composed of only one kind of atom. A compound is a substance the molecules of which are made up of more than one kind of atom.

Figure 1 represents a liquid element,

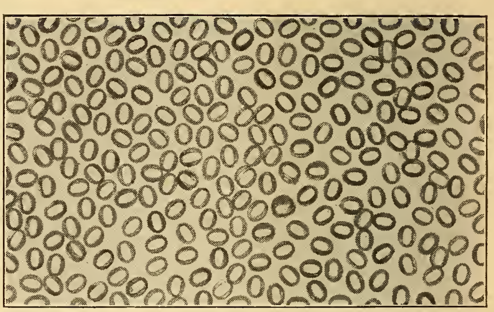


Fig. 1. Atoms of a Liquid

An instantaneous view of a portion of liquid, such as mercury, liquid oxygen, or any melted metal a few hundred-millionths of an inch wide, as seen through an *imaginary microscope* of enormous power. The atoms are in violent vibration continually, this vibration being what we call heat. The "temperature" is a measure of the violence of the vibration. In other words when we "heat" a substance we increase the violence of the atomic vibration.

The almost invisible black points shown in a few places between the atoms are "electrons." These are very small particles, charged with negative electricity, which come out of the atoms originally. They are constantly being knocked out of the atoms by the violence of the (heat) vibration and are constantly going back in again. The number which are "free" at any one time depends on the kind of atoms which make up the substance. In metals there are almost as many free electrons as there are atoms. In other substances there are very few. The electrons exist, it is thought, in large numbers *within* the various atoms. In size the electron is *extremely* small compared with an atom, the size being about one to one hundred thousand, so that even the black points in the drawing enormously exaggerate their size compared to the atoms. The electrons which come out of the atom are all alike.

Figure 4 a liquid compound. Oxygen, hydrogen, carbon, lead, copper are names of some of the elements and *they are, therefore, names of atomic species.* Water, salt, sugar and carbon-dioxide are names of compounds.

Chemical Action.—Chemical action is the name given to the process whenever the groups known as molecules are either formed or broken up. When a substance is burned or when an acid "eats" a metal

we have an action involving the production of new molecules, and therefore new substances, through the rearrangement of the atoms. By an inspection of Figure 5 it will be clear that if two of the "large" oxygen atoms could be separated from their respective water molecules and could then be combined, they would form a *molecule* of oxygen such as one of those in Figure 3. There would be left behind, it should be noticed, four of the "small" hydrogen atoms of Figure 5 (two from each decomposed molecule), and these would stick together in twos and would form two hydrogen molecules. When thousands of molecules were thus broken up the complete process would be called the decomposition of water into oxygen and hydrogen. It is accomplished practically in the laboratory quite easily.

The Atom not Changeable.—Although every one of the thousands of "chemical reactions" which naturally or artificially, are going on in the world all the time, involve the formation or decomposition of *molecules*, no way has ever been found to change an *atom* of one species into one of another species. This was the hope of the alchemists but was never realized. We shall see later that the atoms are not absolutely changeless in their being, but merely that the mysterious forces which preserve their integrity are so much mightier than the forces which hold them together in molecules that as yet man has not been able to shatter them. The atoms have great group loyalty and it is the business of the chemist to make use of this loyalty in the service of man, but the instinct, we might say, of self-preservation is so vastly greater in the atom than his group-forming tendency, that although he submits to the breaking of family ties he will not allow his own individuality to be tampered with.

General Forces of Attraction.—Just as atoms have forces of attraction which hold them together in molecules so molecules attract each other and tend to form the large aggregates which we see around us and call "objects." These forces are, however, in general very much weaker than the atomic, or as we might say, intermolecular forces. They are strong enough, however, to account for the relatively strong cohesion of solid bodies and the weaker cohesion of liquids.

THE NATURE OF HEAT.

All atoms of all substance are in ceaseless motion to and fro. This motion is what we call the heat of a body. The more violent the atomic vibration the hotter the body. It is a great pity that the art of producing motion pictures is not yet developed to the point which would enable us to embody this violent

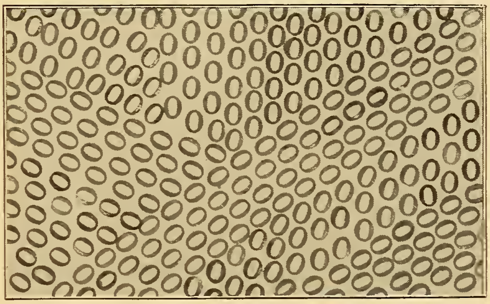


Fig. 2. Atoms of a Solid

An instantaneous view of a bit of a solid substance, such as solid mercury, iron or copper, a few hundred-millionths of an inch wide, as seen through an *imaginary microscope* of enormous power. The atoms are in violent vibration as in the liquid of Figure 1. They are, however, nearer together and their vibration is less. If Figure 1 and Figure 2 represent the same substance in the liquid and solid state, then (1) passes into (2) by cooling, *i. e.*, by reduction of the vibration known as heat. This lessening of the vibration enables the attraction of the molecules for each other to pull them nearer together. When near enough together they suddenly assume an orderly arrangement like children's blocks as shown in Figure 2 and the whole particle, therefore, becomes rigid. The liquid of Figure 1 is then said to have "frozen." The above is fairly representative of any solid element, *i. e.*, any solid composed of only one kind of atoms. Many substances which we call solid probably lack the orderly arrangement of atoms shown above and on the other hand some liquids possess it. The distinction between liquid and solid is that in the former case the vibration is so intense that *any* permanent position of an atom is impossible and it is free to move around among the other atoms while in the latter (solid) the vibration is relatively less and each atom remains in in the same general locality closely held by the attraction of the others.

vibration in the accompanying figures, so we must request imagination to aid incompetent art and endow every atom or molecule of Figures 1 to 5 with a rapid motion; a motion which, like the modern idea of freedom, is limited only by the equal rights of all the other atoms.

Thus in the liquid and solid state the crowding is so close that "the rights of others" allow only vibration through a very limited distance, while in the gaseous state (Figures 3 and 5), the motion consists of a straight line flight until by chance there is an encounter with another molecule. When this occurs there is a "bounce" and then another flight. The distance between the molecules is so small and their speed is so large that literally billions of these impacts are occurring every second in even a cubic inch of gas.

SOLID, LIQUID AND GAS.

All substances which do not decompose (*i. e.*, suffer molecular decomposition) on heating are capable of existing in three states, the *solid*, the *liquid* and the *gas*. The solid when heated above

Fig. 3. Gas Molecules

An instantaneous view of a portion of gas such as oxygen, a few hundred-millionths of an inch wide, as seen through an *imaginary microscope* of enormous power. If the liquid of Figure 1 is heated hot enough the vibration becomes so great that the atoms can no longer stick together as a whole. They fly off in groups of two (in some cases, one, three or more) which are called molecules. These molecules are moving rapidly in all directions. This motion corresponds to the violent vibration of the atoms in the liquid (Figure 1) and, as in that case, represents the *heat* of the substance. The average distance between the molecules is very great compared with their size. They move with high velocity in straight lines like billiard balls on a table, until they strike other molecules or the walls of the containing vessel. Being perfectly elastic, however, they do not come to rest, as billiard balls would, but keep on hitting and bouncing indefinitely.

The gaseous pressure on the walls of the containing vessel, like the pressure of the atmosphere itself, is due to the bombardment of billions of such flying molecules.

In the "photograph," near the center, two molecules are just in the act of hitting. Millions of such encounters happen in a second of time.

In a gas like ordinary air the average distance between molecules is about one thousand times the diameter of one, so that the gas in the "photograph," where the average distance is perhaps only ten molecular diameters, must be considered as a compressed gas.

The above illustration is representative of any element (*i. e.*, substance composed of only one kind of atoms), in the gaseous state, *except* that the number of atoms in the molecules is not two in all substances. It might, in the case of different elements be almost any small number.

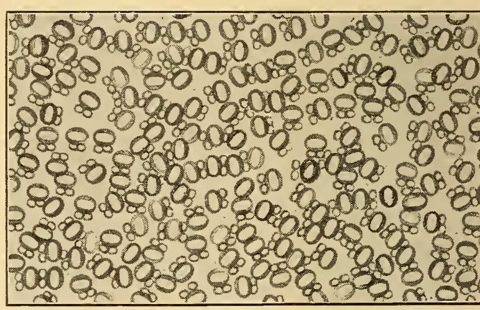


Fig 4. Water Molecules

An instantaneous view of a liquid compound, *i. e.*, a substance the molecules of which consist of more than one kind of atom. The above would be a fair representation of a portion of water a few hundred-millionths of an inch in width. The water molecule consists of one oxygen atom combined with two hydrogen atoms. The only difference between the above and the liquid *element* (say oxygen) of Figure 1 is in the structure of the molecule as already explained. This makes all the difference in the world, however, in the properties of the two substances. The atoms of oxygen when alone as a liquid element do not attract each other enough to form a liquid except when the vibration is very little indeed, *i. e.*, at very low temperature. At ordinary temperature oxygen, therefore, is a gas like that of Figure 3. The water molecules have, however, enough attraction for each other, so that at ordinary temperatures they remain near one another and so constitute a liquid.

its melting point becomes a liquid and the liquid through the process of evaporation or boiling changes into a gas.

The cause of these changes is very easy to understand. We have said that heating a substance really meant increasing the violence of its internal vibration. Now it is clear that when in a solid substance this vibration comes to exceed a certain amount the atoms or molecules will no longer be able to adhere in orderly arrangement but will be forced further apart by the motion and, although not completely out of the influence of each other's attraction, so that they become totally dispersed, still so far apart that they wander about at random, like the frantic members of a mob. Under these circumstances rigidity no longer exists and the substance is liquid.

Fig. 5 Molecules of Steam

An instantaneous view of water vapor or other *gaseous compound.* To form the above it is merely necessary to heat, *i. e.*, increase the vibration of the ordinary water of Figure 4, until the attraction of the molecules is overcome and they fly in all directions. The only difference between the above and the gas of Figure 3 is that the molecules there were composed of two identical atoms while here they are not. That was an element, this is a compound.

When the vibration gets still more violent, *i. e.*, when the liquid is further heated, the numbers of the molecules at the surface of the liquid which escape into the surrounding region become very large. The molecules which escape do so because amid the random vibration they happen to have a speed sufficient to carry them up beyond the attraction of the other molecules of the liquid. When the space around gets filled with these molecules they constitute a gas.

"*Heat Expands.*"—It will be clear from the above why "heat expands." The more violent the internal vibration the further the atoms or molecules are forced apart and the more space is occupied by a piece of the substance.

Note:—In the next article Dr. Comstock will further discuss the properties of atoms and describe some of the habits of the other fundamental reality—the electron.—The Editor.

NEW TYPE OF CANAL LOCK

There has been recently put into service on the New York State Barge Canal a type of lock which is new in the United States, although it has been used for several years in Germany.

The distinguishing feature of this type of lock is the absence of large submerged valves. The water both for filling and emptying the lock flows through siphons, the crests of which are above the water level. These siphons are made of reinforced concrete. The vacuum necessary to operate them is produced by a separate closed tank which is allowed to fill with water. A valve is then opened below this tank and the water is thus held in suspension by the vacuum which its weight has caused.

When it is desired to fill or empty the lock, as the case may be, communication is opened by means of a pipe between the top of the proper siphon and the top of the tank. This causes a vacuum to be formed in the siphon and the water starts to flow. When it is desired to stop the flow communication is opened between the siphon and the atmosphere which at once breaks the stream in the siphon. The vacuum tank is connected in such a way that it automatically refills.

This type of lock is slightly cheaper in first cost than the lock of the same type with submerged valves, but its great advantage is the reduced cost of operation and maintenance through the abolishing of large submerged valves and the mechanism necessary to operate them.

L. E. M.

ANIMAL CELLS INDEPENDENT OF THE BODY

GROWING NORMAL AND PATHOLOGICAL TISSUES AFTER REMOVAL FROM THEIR HOST—RESEARCHES OF DRS. CARREL AND BURROWS OF THE ROCKEFELLER INSTITUTE

THE laboratories of the Rockefeller Institute for Medical Research are continually making investigations that are of notable and far-reaching value, and the recent work of Drs. Alexis Carrel and Montrose T. Burrows on the cultivation of tissues after removal from animals and human beings may mark the beginning of studies that will lead to the discovery of effective methods for the treatment and cure of cancerous and other growths.

Some remarkable work done by Prof. Ross G. Harrison of Yale University gave Doctors Carrel and Montrose their first ideas.

Professor Harrison's study is worthy of notice here on account of its bearing on the work of these investigators in the Rockefeller Institute.

Professor Harrison studied embryonic transplantation and the development of the central nervous system. It has been disputed by embryologists as to whether the nerve fibres were mere outgrowths of nerve cells or whether they were formed independently in the tissues which they were ultimately to supply and by some means became attached to the nerve cells in the ganglia. In order to test this experimentally, Professor Harrison removed from embryo frogs fragments of tissue containing nerve cells but which showed no sign of differentiation into nerve fibres. These fragments were placed in a drop of lymph obtained from an adult frog, mounted on a hollow microscopical slide and sealed with paraffin to prevent the specimen from drying up.

After a day or two the specimens when examined under a microscope, showed, in a considerable number of cases, nerve fibres extending out from the fragment of tissue into the lymph. At the end of various periods, reëxamination showed that the fibres were longer, having grown. This investigation effectively proved that the "outgrowth" theory of nerve-fibre development is correct, and that the fibres are processes put out by the nerve cells and are specifically nervous in origin.

This discovery is most interesting in itself, but the great importance to be attached to it lies in the fact that it opened the door for further investigation as to the possibility of growing tissues when entirely removed from their host.

It is a well-recognized fact that the cells of an organism can often live independently of the body for a short time after removal. This is easily demonstrated by the white corpuscles of the blood and at times in the continuation of the action of organs after removal. The continued rhythmic contractions of the heart of a frog after extirpation is a common instance of this.

Burrows in the spring of 1910 developed Harrison's technique for warm-blooded animals and was successful in cultivating various tissues from fragments removed from a sixty-hour embryo chick.

Carrel with Burrows recently reported that they have been able to extend the investigation to tissues of adult warm-blooded animals with remarkable success.

The method used consists of extirpating small fragments of the tissue being experimented on, and introducing these fragments into a medium made from some of the blood plasm of the animal.

These small pieces are placed in a hollow glass slide, properly sealed, and put into an incubator and kept at body temperature. Great care has to be taken to maintain as strict aseptic conditions as in surgical operations. In order to prevent a chilling of the specimens when being examined microscopically, the microscope used is likewise placed in a thermostat regulated to the same temperature.

In their first series of experiments dogs and cats were used. Fragments of connective tissue, cartilage and bone were first tested, and the experimenters were able to cause the formation of new cells from the pieces taken. They also were successful in cultivating the skin of an adult frog in a similar manner.

Pieces of organs were next tested, and they were able to grow thyroid gland, spleen and kidney tissue. In the case of the kidney tissue they obtained evidence of the formation of new urinary tubules.

A further study proved that if these new cells were removed and placed in a fresh plasm medium they could be made to proliferate further and a second generation from the first culture of cells was thus made. The tissue of the thyroid gland was used in this experiment.

In a second report from these workers, they give an account of the successful cultivation of fragments of a very malignant cancer (sarcoma) when removed from the body. The cancer experimented on was one affecting fowl. It was found that the new cancer cells were formed very soon after the preparation was made, the tissue showing activity in some instances in two and one half hours. A second generation of these cancer cells was also obtained.

It is a natural step from an investigation of animal cancer to that of human origin, and Doctors Carrel and Burrows were similarly successful in cultivating a human cancer (also a sarcoma).

The case reported by them was cancer of one of the bones of the leg of a woman thirty-five years old. As this particular operation may be of historic interest, the following facts are given: The patient, who had had two previous operations for this cancer was operated on by Doctor Colly in the Memorial Hospital in New York, on October 27, 1910. The growth was extirpated and fragments of the cancer were inoculated into a medium made from the blood of the patient. Twelve preparations were made and ten of the cultures gave positive results and showed the production of new cells. One of these preparations was still alive at the end of a week.

Prophesies are always fraught with danger, but it does not seem altogether unreasonable to imagine that the further study of this subject may lead to a more thorough understanding of the mechanism of the growth of tissues both normal and pathological and as a result lead to the discovery of means to inhibit the development of abnormal growths.

It also may permit the study of the growth of living tissues when infected with disease-producing germs and lead to a better understanding of numerous parasitic diseases.

The field that has been opened by these investigators seems to be a large and promising one, and it is not improbable that it may mark another great advance in the history of biological investigation, an advance that will give to mankind more effective means of combating those diseases which annually take a tremendous toll, and against which modern sanitation is all but powerless.

S. M. G.

Up to December 1st the Aëro Club of France had issued over 270 licenses and the total number of aviators in the world was about 500. The deaths had been about 6 per cent. The total distance flown may be estimated at 125,000 miles, or one death for 4,166 2-3 miles.

EVOLUTION OF THE ULTRAMICROSCOPE

DESCRIPTION OF THE APPARATUS WHICH WOULD MAKE A BILLIARD BALL LOOK TWENTY TIMES AS HIGH AS THE SINGER BUILDING

BY ELLWOOD B. SPEAR

When the German emperor in the legend of the "Spectacular Ruin" by Mark Twain decreed that all his people should wear spectacles the stockholders in glass factories in those days doubtless joined heartily in "Long live the king." Incidentally science got a forward push because every man wore on his nose the simplest form of microscope that has yet been devised by the employment of glass. The most wonderful microscope is the eye, and if our vision becomes dimmed by old age or overwork we aid this perfect instrument with a simple form of microscope, viz., spectacles. We can see better with glasses on because the letters and the spaces between the letters appear to be larger. The increasing of the size of the picture that an object makes on our brain is the chief function of the microscope.

A very simple little microscope may be made from a drop of water or a tiny bulb of glass filled with water or other transparent liquid. Take a piece of windowpane or a glass plate and grease the surface; place two tiny particles of sand side by side and on one let a very small drop of water fall. The drop will assume a spherical shape on the greased surface and it will be seen that the particle under the drop appears much larger than the other. In fact, an object viewed through a curved transparent surface appears enlarged. This, then, is the secret of the betterment of our vision by means of spectacles, the center of the glass is somewhat thicker than the edges and we are therefore looking through a curved surface. The picture that reaches our brain is thus increased in size, and the amount of increase depends upon the degree of curvature; that is to say, the nearer the surface approaches to being spherical the larger the picture will become. The increase also depends upon the material of which the lens is made because some substances enlarge the picture much more than others. A piece of transparent substance with a curved surface used for enlarging the picture of any object is known technically as a "lens" and the enlarged picture itself is called the "image." Spectacles and microscopes are, therefore, inanimate candidates for membership in the Ananias and nature fakir clubs because we see only the image of the object in question and not the true picture that the unaided eye would otherwise give us.

Simple microscopes such as we have been considering have been used since the earliest times. About the seventeenth century some Edison of those days, believing in the principle of pushing a good thing along, conceived the idea of putting two lenses one upon another, and thus still further increase the duping of the eye. This sort of instrument is known as a "compound" microscope. The splendid instruments of the present day are made on essentially this principle. The well-diggers in the local option districts also contributed to the evolution of the microscope by rediscovering what was known to the cave dwellers, namely, that the stars could be seen in broad daylight from the bottom of a well without letting a brick fall on the operator's head. Employing this principle scientists discovered that an object could be seen much more distinctly through a microscope if the lenses were enclosed in a tube so that no light came in from the sides

between the object and the operator's eye.

As a next step it was found that if the space around tiny particles were lighted from underneath, the particles themselves being darker could be seen against the well-lighted background, much better than if the light were allowed to fall directly on the object, and this principle is employed in most microscopic work. The limit of the enlargement by means of this type of microscope is about 1,500 times. The smallest particle visible to the naked eye is about 1-160th part of an inch and the limit of the microscope would therefore be roughly 1-250,000th of an inch. If we could look at a pea through our most powerful microscopes it would appear to be a huge globe fifteen feet high and to contain enough material to make soup for a good-sized town. A billiard ball viewed under these circumstances would appear as high as the Singer building in New York.

The human mind is, however, never satisfied and scientists, applying the wet cloth and ice once more to their temples realized that the electric lights of a city can be seen much farther at night than during the daytime; in other words, a lighted body shows up best against a dark background. Two of these scientists, Siedentopf and Zsigmondy, saw that the principle employed in the ordinary microscope for viewing very small bodies was wrong and that, instead of lighting up the space around the particles and looking at them in the shadow, we should light up the particles themselves as much as possible and keep everything else dark. If a ray of sunlight is allowed to come into a darkened room through a small hole in the shade where sweeping or dusting has been going on the path of the ray across the room is plainly visible if one stands at right angles to the direction in which the ray is going. A glass of turbid water held in the ray shows the same phenomenon. This is technically known as the Tyndall effect and is named after the famous physicist.

This, then, is the principle on which the "ultramicroscope" is constructed and is the same by which we see the planets. The sun shines on the moon, for instance, and she is plainly visible to us against the black space beyond. The ultramicroscope is then an instrument for throwing intense light on the small particles themselves and not allowing any of this light to come into the observer's eye except that which is reflected from the particles. It should be noted that, contrary to the popular conception, the ultramicroscope has nothing to do with ultraviolet rays. It is called "ultra" because it makes visible particles that are "beyond" the range of the ordinary microscope.

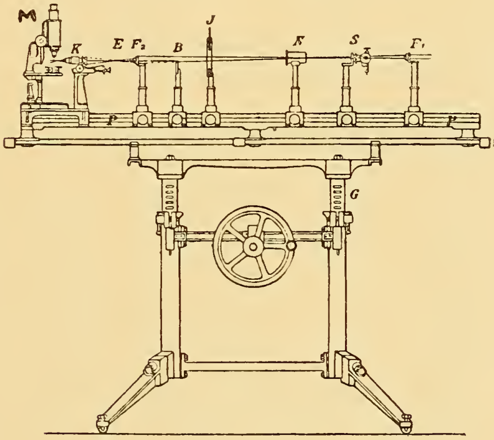


Fig. 1

Figure 1 is a cut of Zsigmondy's ultramicroscope with its stand. M is an ordinary microscope of low power and the particles to be viewed are brought under M in a little vessel e (Fig. 2) which is made of quartz or glass. All the appurtenances from K to F, are merely lenses employed to condense the light rays at the point directly under the microscope where the particles come, or are diaphrams to cut off all the useless rays that would otherwise disturb the illumination of the particles. The light which enters at F is either the direct rays of the sun or those of a powerful arc lamp. Particles of such small dimensions must, of course, be suspended in some suitable medium like water or other liquid.

Transparent solids such as glass may also be used. The limit of visibility with the ultramicroscope is roughly 1-5,000,000 of an inch; that is to say that a particle may be visible with this instrument that is twenty times too small to be seen under an ordinary microscope. Here again the instrument is a deceiver because we do not see the particle at all, but merely a halo of light that is reflected from its surface. A pea, then, illuminated by the ultramicroscope would appear as a huge ball of fire a couple of hundred feet in diameter.

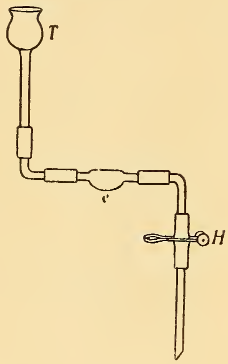


Fig. 2

The ultramicroscope has made possible a much more thorough study of a great many liquids containing very small suspended particles and technically known as colloidal solutions. An article on this subject will appear in a later issue of Science Conspectus.

THE ANCIENTS USED REINFORCED CONCRETE

It will be something of a surprise to learn that the art of making reinforced concrete is not an invention of recent years as might be supposed, but is now known to date back to a period before the birth of Christ. Mr. H. K. Dyson, in the course of a recent address in London, England, described the construction of the roof of a Roman tomb built earlier than 100 B. C. This consisted of a slab of lime concrete in which bronze rods were placed crossing each other to form a reinforcing lattice work. Masonry reinforced by timber and tiles was not uncommon in Rome. One point of the great wall of China on treacherous subsoil was built on a kind of concrete raft in which timbers, reeds and rushes were imbedded. The first printed suggestion embodying the idea of the reinforced concrete of modern times appeared in 1830. It was then suggested that flat roofs could be made of cement with a lattice work of iron rods thickly imbedded in it, and the whole covered with flat tiles. In 1840 similar constructions were used for floors in Paris although the material used was plaster of Paris instead of concrete. It was found, however, that plaster of Paris caused imbedded iron to rust, and it is probable the delay in the development of reinforced concrete construction was due to the lack of suitable cement. Portland cement was invented in 1824, but it was not manufactured in large quantities until many years later. The first real inventor of reinforced concrete in the modern sense was a plasterer of Newcastle-on-Tyne, who took out a patent in 1854. In America, W. E. Ward erected a building in 1875 containing reinforced walls, floor beams and roof. Ernest L. Ransome who developed modern reinforced concrete construction in this country was among the early patentees covering methods largely in use today.

"COASTING" ON RAILROADS

Recent tests on elevated roads in New York and in the Philadelphia subway have indicated that a saving in power of from twenty-five to thirty-five per cent. may be accomplished by judicious "coasting"—that is, allowing the cars to run by their momentum with the current turned off. In this connection it is interesting to note that on the Second Avenue line in New York a check is kept on motormen by coasting clocks on the trains which automatically indicate what part of the total running time has been spent in coasting.

POSSIBLE IMMUNITY FROM LEPROSY

EXPERIMENTS OF DR. DUVAL WHICH MAY LEAD TO THE DISCOVERY OF A SERUM CAPABLE OF COMBATING THE INFECTION IN MAN

Leprosy is a disease that has always been most widely feared and an occasional case in a locality where the disease is rare becomes an absorbing topic throughout a wide area. The strange nature of the disease and the mutilation that it often causes combined with a general ignorance of its nature and ancient historical accounts, have given rise to a great feeling of dread for the leper and, in consequence, unfortunates suffering from the disease have oftentimes been most harshly and inhumanly dealt with.

It has been well established of late years that the disease is not acutely contagious and that a short period of contact with a leper is probably never sufficient to produce a fresh case.

In 1909 there were 139 recognized cases in the United States, 764 in Hawaii, and 2,330 in the Philippines. It must be remembered, however, that there are some unrecognized cases, and other cases which, although correctly diagnosed, are not brought to the attention of the health authorities.

The treatment of the leper in the past has been nearly hopeless, although certain American doctors in the Philippines have obtained some improvement in cases of leprosy by treatment with a substance known as nastine.

The parasite that causes the disease was discovered by Hansen in 1874 and is known as the *bacillus lepræ*. Many attempts have been made to grow this organism in pure culture on artificial media but without success.

Clegg in the Philippines was able to grow organisms obtained from lepers, similar to and probably identical with the leprosy bacillus, but in order to do this he had to mix his material with amœba and certain bacteria capable of growing with these low forms of animal life. As a result his cultures contained (1) amœbæ, (2) the other added bacteria, (3) leprosy bacilli and therefore were not pure cultures.

Dr. Charles W. Duval, professor of pathology and bacteriology, at Tulane University, has recently been able to make improvements in the bacteriological technique in leprosy that may have an important bearing on the prevention and cure of this abhorrent disease.

Dr. Duval confirms Clegg's work and further reports that he has been able to grow the organism in pure culture on a medium composed of pieces of sterile banana treated with solutions of certain organic salts. He was able to isolate the organism from four cases of leprosy. The organism grows slowly and, unlike other disease-producing bacteria, develops more rapidly in the presence of light than if kept in a dark incubator.

The experimenter was able to transmit the disease to Japanese dancing mice by inoculating some of the cultures thus obtained. These animals developed typical leprous lesions in four to eight weeks after the organism had been introduced into their systems. Sugai had previously demonstrated that this species of mouse was susceptible to leprosy bacilli that had been taken directly from the tissues of a leper.

Doctor Duval found that guinea-pigs, rabbits, rats and ordinary mice were apparently immune, as none of these animals showed any result following inoculations with the cultures.

It is a well-known fact that there are a number of organisms which show morpho-

logical and staining characteristics similar to those of the leprosy bacillus. Amongst these might be mentioned the bacillus of tuberculosis and certain other non-disease-producing organisms found in grasses and at times in butter and other dairy products. Doctor Duval considers these and gives evidence to prove that the cultures he obtained from the human tissues of the four cases are true leprosy bacilli and not any of the species referred to in the preceding sentence.

Doctor Duval states that "the successful cultivation of the *bacillus lepræ* and the fact that the cultures retain pathogenic properties are of commanding importance in respect to a possible production of an artificial immune serum for combating the infection in man."

Work along this line is already in progress in Doctor Duval's laboratory and it is to be hoped that as a result vaccines or sera may be produced that can be used for both curative and preventive purposes.

The full paper by Doctor Duval is published in *The Journal of Experimental Medicine*, Vol. 12, No. 5, pp. 649–665.

S. M. G.

A PROBLEM OF TELEPHONE DEVELOPMENT

A PAPER was read by John J. Carty, general engineer of the American Telephone and Telegraph Company, and member of the Society of Arts, before the International Conference of European Telephone and Telegraph Administrations at Paris in September, in which he compared automatic telephone machinery with manually operated apparatus. His analysis brings out the relative merits of machinery and trained operators in the telephone field and shows that the Bell apparatus now used contains many automatic features, but is generally controlled by operators at the central exchanges. He showed that in the so-called automatic systems, many skilled mechanics are required to keep the apparatus in working condition and in attending to special classes of calls. In point of fact, neither system is wholly automatic or wholly manual, and the problem is to find out to what extent it is desirable to employ human agency. The success of the Bell system, in the face of almost overwhelming obstacles, shows how much can be accomplished by vocational training of telephone operators and by providing them with the best and most convenient means for increasing expedition and accuracy. The subject-matter of this paper is receiving the greatest attention in view of the enormous development that is constantly going on in the telephone field.

THE ECONOMICS OF RAILWAY ELECTRIFICATION

THE question of choosing between the different systems of electrification for steam railways is rather an economic than a purely engineering problem. Roughly it appears that the cost of line, etc., is much less for the alternating current system than it is for the direct current system. The cost of the alternating current motors is greater than that of direct current motors. From this it will be seen if 100 miles of track were to be electrified and one locomotive used the most economical scheme would be the alternating current. If, however, one mile of track were to be electrified and 100 locomotives used the direct current would be the most economical.

In deciding which of the two systems to use, it is necessary to strike an economic balance between the first cost of the line and the first cost of the locomotives or motors. When many motors are run comparatively short distances the direct current appears to have the best of it. When a smaller number of motors are to be moved long distances the alternating current would seem to be more advantageous. It is evident that the problem is not so much one of pure electrical engineering as it is of broad engineering economics. L. E. M.

SCIENTIFIC METHOD IN PUBLIC WORKS

At the 671st meeting of the Society of Arts held on December 13, Mr. Louis K. Rourke, superintendent of streets, Boston, spoke on "The Scientific Administration of Public Works." He said in part:

The watchword of the present day seems to be "efficiency." In fact, many people are demanding efficiency in public work, national, state and municipal; not only demanding it, but securing it to some extent. I think there is more waste or inefficiency from the improper handling of men than from any other source. The study of efficient handling of men is not given the importance which it seems to deserve in our scientific institutions. The student is left to handle this subject as chance or his own will may direct after leaving school. It seems to me that much more might be done than is being done by our technical institutions to give the student a start, at least, in this very important subject of handling men. In my career, at least, the greatest problem has been to secure efficient work from men. To my mind the first principle in securing efficiency is to concentrate authority and responsibility.

For this reason I have not much use for boards or commissions as executive forces. Largely, wherever a commission accomplishes good work it is owing to the predominance of some one member. Whenever there are several predominant members or none at all very little is accomplished. The most efficient public work I know of in execution today is the Panama Canal. Our national government will spend about 375 millions on this gigantic work. Something over two thirds of this amount has been spent up to date, of which about 100 millions has been spent in wages. The work is practically all done by day labor under the supervision of men most of whom are educated and trained in the line of work which they are directing. The American people may well be proud of the results being obtained from the efficiency standpoint. The Isthmian Canal Commission itself I consider a useless appendage to the organization, and I was very sorry to see the Mann bill, which provided for the abolishment of the commission, pigeon-holed.

Up to July, 1907, the organization of the Panama Canal work was entirely functional. At this time a radical change was made in the Culebra division, making the organization of this division almost entirely territorial rather than functional. In the fall of 1907 the territorial organization was applied to all the constructive engineering work on the zone and since the fall of 1907 this form of organization has been adhered to, and the improved results have justified it.

When I came to Boston as superintendent of streets I found the street department in much better shape than I expected, a condition which I consider due to the efficiency of my predecessor, Mr. Emerson. In looking over the ground, however, I found three departments whose work overlapped each other, so that in some cases it was an impossibility to fix responsibility for work which was not done at all or improperly done. These departments were the city engineer's department, the water department and the street department. I found the city engineer's department had no fixed responsibility or authority, with the possible exception of new bridge work. It is practically a consulting department without executive authority.

The water department, with practically all of its work in the streets, was independent of the street department. The street department which is the large executive engineering department of the city, and I might say the chief political department of the city, was independent of the other two departments. It seemed to me that this form of organi-

zation or disorganization tended to inefficiency. I therefore had the law department prepare an ordinance bringing these three separate departments under one head. This ordinance was passed by the council and approved by the mayor to take effect February 1.

Under the proposed organization of this new department the territorial form of organization is adopted as far as possible. The department will be divided into three divisions, each under a division engineer whom I consider an expert in his line. The divisions will be the underground division, consisting of the sewer and water works, the overground division, consisting of the street paving, lighting, cleaning, oiling, watering and the handling of refuse. The bridge and ferry division will handle all the bridge work, grade-crossing work and the ferries, which may be considered as floating bridges.

If this plan works out, and the only reason why it might not work out would be the incompetency of the head of the department, the city will receive greater benefits from increased efficiency and a field will be opened to engineers in municipal work which has been too long closed.

In speaking of the plan possibly failing from the incompetency of the head of the department, the head of this department must be an executive engineer who knows how to handle men as well as to advise on the merits of engineering plans. He must have backbone enough to run the department on the "square deal" basis and not allow irresponsible people to dictate what he shall do.

In the promotion and employing of men in the department efficiency will have the first consideration. The criticism of this organization has been made that by it we are liable to drag the engineering department into politics, which, up to date, has been kept out of politics. As I have already stated there is not much left of the engineering department, and as to its being out of politics, opinions may differ on that point. However, as regards endangerment of the department on account of politics, that depends entirely on the commissioner and his division engineers. If they are the proper men for the places, nothing will interfere with them; if they are not they should be replaced.

There is just as much chance, if not more, for politics to interfere with the present organization as there will be with the new department; in fact, there is less chance for political interference in the new organization because the organization will call for only one political appointee while the present organization calls for three. Criticism has also been made that the commisisoner is his own engineer of design as well as execution and that it will be difficult to find a man who can combine the two qualifications.

Regarding this criticism, I will say that the division engineers are experts in their individual lines, and they will have the necessary assistants to prepare all plans, with the general approval of the commissioner, and it is not expected that the commissioner will be obliged to check up all the details personally. Furthermore, the engineering work of the city is principally maintenance work rather than constructive, and if any new and strange engineering problems arise, naturally the commissioner will avail himself of any expert advice or assistance which he may consider necessary.

SUCCESS OF PANAMA CANAL PLANS

It is worthy of note that the silence of the newspaper press is one of the best evidences of the successful carrying on of the work at Panama. This work is being conducted in an extremely efficient manner and probably as economically as is possible under the circumstances.

The recent tribute of the American Institute of Mining Engineers, who visited the canal in a body is as unusual as it should be gratifying to the people of the United States.

THE SOCIETY OF ARTS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Society of Arts was established as a department of the Institute by President Rogers in 1861. It is especially devoted to the general dissemination of scientific knowledge, and it aims to awaken and maintain an interest in the recent advances and practical applications of the sciences.

Any person interested in the aims of the Society is eligible to membership.

The annual dues are $3.

COMING LECTURES BEFORE THE SOCIETY OF ARTS

On Wednesday, February 8, the Society of Arts will be addressed by Dr. William T. Sedgwick of Boston on "Science and Human Welfare," which will be largely a disquisition on the intimate relations of pure and applied science to modern society.

We regret that President Nichols, of Dartmouth College, will be unable to address the Society of Arts this season. Among those who have accepted invitations to speak before the Society are Prof. Edmund B. Wilson, professor of zoölogy at Columbia University and Prof. George W. Ritchey of the Mt. Wilson Solar Observatory, Pasadena, Cal.

NEW MEMBERS OF THE SOCIETY OF ARTS

At the meeting of the society, held Tuesday, December 13, the following applicants for membership were presented and elected:

Charles Almy, Jr., Research Laboratory, M.I.T.
Stephen E. Barton, 4 Liberty Sq., Boston.
Warren H. Colson, 184 Boylston St., Boston.
William A. Copeland, 365 Hammond St., Chestnut Hill.
Thomas Doliber, 291 Atlantic Ave., Boston.
Ralph C. Emery, 114 State St., Boston.
Frederick A. Flather, 68 Mansur St., Lowell.
Carl T. Keller, N. E. Tel. & Tel. Co., 119 Milk St., Boston.
Lindsley Loring, Fox Hill St., Westwood.
James A. Lowell, Chestnut Hill.
S. M. Merrill, 120 Boylston St., Boston.
William W. McClench, Springfield.
George H. Nutting, 119 Aldrich St., Boston.
Alexander M. Paul, 359 Broadway, Winter Hill.
Russell A. Sears, 101 Milk St., Boston.
William D. Sohier, 79 Beacon St., Boston.
James Solomont, 41 Georgia St., Roxbury.
F. W. Stearns, 269 Park St., Newton.
P. F. Sullivan, 84 State St., Boston.
George C. Travis, 101 Milk St., Boston.
Horace W. Wadleigh, 234 Commonwealth Ave.
Horace E. Ware, 110 Summer St., Boston.
Albert P. Williams, 278 Crescent St., Waltham.

At the meeting of the society, held Tuesday, December 20, the following applicants for membership were presented and elected:

James D. Colt, 53 State St., Boston.
Robert Douglas, 166 Essex St., Boston.
J. P. Eustis, Ames St., Cambridge.
Isaac F. North, 70 Montvale Road., Newton Centre.
P. A. O'Connell, 155 Tremont St., Boston.
William Lowell Putnam, 49 Beacon St., Boston.
C. N. Quimby, 60 Hillside Ave., Arlington Heights.
Frederic S. Snyder, 55 Blackstone St., Boston.
Thomas G. Washburn, 68 Pemberton Sq., Boston.
John F. Wilson, 90 Chauncy St., Boston.

"STELLITE" A NON-CORROSIVE ALLOY

An alloy of cobalt and chromium is reported to have been recently made by heating the mixed oxides of these metals with pure powdered aluminum. This alloy has been named stellite.

It was first made by fusing in an electric furnace and afterwards in a special natural gas furnace. It melts to a perfect fluid and has been cast in bars from one quarter to one-half inch square. It will forge into thin strips said to be as hard as mild tempered steel.

Perhaps its most remarkable property is its non-corrodibility. Exposure to the atmosphere has practically no effect on it. It is not readily attacked by acids, even a mixture of sulphuric acid and bichromate has practically no effect. A kitchen knife made of this substance was used for two years with no sign of tarnishing.

If suitably polished it is a lustrous white in color. It permanently retains its finish. A cast bar of this material showed an elastic limit of 79,000 pounds, an elongation of three per cent. and an ultimate strength of 96,000 pounds to the square inch.

Although this alloy is very hard it forges readily at a red heat. Its elastic limit is not quite equal to that of tool steel of the same hardness, but it is said to be much tougher. The hardness of the material apparently depends upon the relative proportions of the cobalt and chromium, and when very hard the breaking stress and elastic limit very closely coincide. It is claimed that a steel lathe-tool has cut ordinary steel at a speed of 200 feet per minute at which speed the high-speed alloy steel tools failed almost at once. Blades made from this alloy take a fine cutting edge, although a razor made from a cast bar of this material and used for shaving some hundreds of times, is said to have been inferior to a good steel razor because it requires more stropping.

It is not claimed that the material is superior to steel for tools, but it is claimed that it is non-corroding and that it will stand higher cutting speed without burning.

Stellite when it contains 25 per cent. of chromium is not magnetic although it does not yet appear with what per cent. the well-known magnetism of cobalt disappears.

Stellite will probably find its widest use for small cutlery since it retains its edge and keeps its lustre. It may be found useful for surgical instruments as it is not at all affected by the sterilizing solutions which so severely corrode steel instruments. From a rough estimate it appears that this material would cost in the neighborhood of from twenty to forty cents a pound. L. E. M.

IMPERVIOUS COATINGS FOR CONCRETE

In a recent paper read by Leonard Wason, member of the Society of Arts, before the National Association of Cement Users, he states that the dust produced by concrete floors is no more than is produced by wooden floors, but in the latter case, it finds a hiding place between the cracks of the boards. He recommends two coats of boiled linseed oil carefully applied and thoroughly hardened. Another suggestion to do away with dust of concrete floors is to cover the surface of the concrete with water glass (sodium silicate). The surface of the concrete should be kept damp after the placing of the concrete and should then be washed and allowed to dry thoroughly. Water glass should be mixed with four to six parts of water according to the surface to be treated. The denser the surface the weaker should be the solution. Apply with a brush after four hours, and within twenty-four hours wash off the surface with clear water. After drying apply another coat of water glass solution repeating the process above until three or four coats have been applied. This treatment is also recommended for tanks and vats, and is said to make them impervious, odorless and sanitary.

SCIENCE CONSPECTUS

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THE ERUPTION OF ETNA IN 1910

FRANK A. PERRET, CAV. UFF. D'ITAL., TELLS THE SOCIETY OF ARTS OF HIS EXPERIENCES ON THE VOLCANO DURING THE ERUPTION AND IN MESSINA AFTER THE EARTHQUAKE

IT IS well known that many volcanoes in the same region of the earth are interconnected, and one of the points which I wish to bring out is to show, if possible, the interrelationship between the Messina earthquake and the activity of Mt. Etna and Stromboli. In order to do this, I am going to touch on the subject of the Messina earthquake and also of a little eruption of Mt. Etna which occurred shortly before the earthquake.

Most of you are aware of the fact that I believe that the only way to study a volcanic eruption is to study the eruption. In other words, not to visit the volcano after its activity has ceased but to live upon the volcano during the eruption, and as nearly as possible to the scene of action. In this way it has been my privilege during the past six years to live upon Vesuvius during the great eruption of 1906, Stromboli in 1907 and Mt. Etna in 1910.

The first of the events about to be described is a small eruption of Mt. Etna. The activity of this volcano has manifested itself during the past three hundred years at intervals of six years on an average. That is to say, there have been during this time seventeen eruptions per century. This being the case, it was not surprising when an eruption of Mt. Etna did not occur for sixteen years that one should have been looked for.

Mt. Etna is one of the great volcanoes of the earth. It is great in size, great in activity, great in beauty.

As to its activity, I have described it in saying that it has an eruption on an average of every six years, and as to its power, one of these eruptions some centuries ago killed 80,000 people, which is probably more than Vesuvius has ever done in all its existence as a volcano, not excepting the great eruption of 79 A. D., which destroyed the cities of Herculaneum and Pompeii.

As to its beauty, this is also very difficult to describe. It is teeming with life, animal and vegetable, and is snow covered one half the year, the other half it is bare to its very summit. A certain professor, well known for his self-conceit and egotism, was heard to exclaim, "Etna is the most beautiful thing on earth. It is the abode of the gods; I lived there six weeks." I believe this refers to Etna in times of peace; I am sure that Etna in eruption would seem more fitted for the abode of a different order of beings.

The observatory stands very near to the central crater, about 1,000 feet below the summit. This is made possible only by the fact—and a very important one—that all the great eruptions of Etna in modern times do not take place from the central crater. The mountain is rent open on the side and the eruptive forces find their vent and form craters upon the flanks of the volcano.

Messina—View in the Corso Cavour, showing obstructions in the Street

The small eruption of the 29th of April, 1908, although it was, in itself, of no great importance, acquires an interest from the fact that in the first place it broke the repose period of sixteen years, and in another way it has proved to be very important in being not merely the precursor, the forerunner, of this greater one of last year, but its prototype as well. That is to say, these two eruptions, while it would be rash to affirm that they mark a new era in the type of Etnean eruptions, nevertheless form a class which has been comparatively rare. It is characterized by the production of a long fissure with a large number of eruptive mouths distributed along its length, with a very rapid outflow of lava from the lower end of the fissure. The explosive effects are weakened by distribution over so many vents and the formation of cones around the craters by accumulation of detritus is on a very small scale.

This eruption of the spring of 1908 lasted but twelve hours, and after so long a period of repose you will readily understand that we could not have for one moment imagined that the internal conditions of the volcano or the subterranean volcanic forces of that region would be satisfied with so small an outbreak. Therefore, it was with considerable anxiety that I watched events in that region. By an astronomical calculation, which I will not be able to enter into, it was found that December of that year might be considered a dangerous month for events of this kind; that is to say, for volcanic eruptions or earthquakes. Taking that in connection with the nervous condition of Etna which could not be satisfied with so small an outbreak as this, I accordingly feared for the safety of that whole region, and when at Messina in the summer of 1908 I visited Dr. Cheney and his wife, our American Consul there, they asked me if

I thought they were in any danger there at Messina I couldn't help saying that I feared for the month of December, and, as I was in this country in November, I hurried back in order to be on hand in the case of anything happening. I arrived at Naples on the 25th of December and three days later occurred that most awful earthquake in which nearly 200,000 persons lost their lives in about thirty seconds.

Dr. Cheney and his wife were killed in this earthquake, and I afterwards learned that they had purposed spending December in Naples. Whether or not this was on account of what I had said I, of course, do not know and I like to think that they thought of doing so but felt that to leave at such a time would be deserting their post of duty.

After this earthquake, what happened? The activity of both Etna and Stromboli, such as it was, suffered a very decided diminution. I visited both the volcanoes after the earthquake and was more and more impressed with the general although indirect interrelationship between them and the seismic event. The earthquake relieved the strain for the time; nevertheless, the great eruption of Mt. Etna had not occurred and it was therefore only right to expect something of this kind, and, finally, on the 23d of March of last year, there occurred the greater eruption.

Another long fissure, a mile and a quarter in length, opened on the south flank with twenty-four small eruptive mouths, and from the upper portion at first and later from the lower portion there flowed this rapid stream of lava. It flowed for a distance of about seven miles and threatened the towns of Bellpasso and Borelli, and would also have menaced the larger town of Nicolosi had it not been that its course was diverted frequently by the intervening hills resulting from other eruptions. This lava, with a speed at its source of eleven miles an hour, flowed down the mountain side more and more slowly, spread wider and wider as it advanced, until it attained in some places a width of nearly a mile and a depth by accumulation of some 150 feet.

Messina—Ruins of a tall poorly constructed building.

I am going to take you for a moment to see about a dozen views of Messina. I arrived there the second day after the

event, and, as you will see from the seaside, the town does not present a picture of absolute destruction. Many walls remain here along the water front and one would suppose that some of the houses remained intact. This, in fact, was not the case, and on getting ashore it was seen that while the façade of this building had remained, inside the floors had collapsed and buried the inhabitants beneath them. A continuous procession of the dead and injured was met at every turn in Messina during those days and on all sides corpses were lying about in the street.

Messina—Direction of maximum motion shown by zig-zag lesions of brick chimney

The general idea of the collapse of the buildings and of the poor construction of the same is shown in the views. The walls were built of what we would call rubble and this with mortar of a poor quality gave no power of resistance to the walls against the shock. This form of wall is capable of supporting a steady weight but is incapable of withstanding the vibrations of an earthquake. The floors were very weak and most of them fell through and in a few places where brick was used the wall was very thin in proportion to the height of the building.

In investigating earthquake phenomena, one of the most important things to determine is the direction of the shock, and for this purpose to my mind a round brick chimney is one of the very best of indicators. You will see from the zig-zag lesions upon the sides of the chimney shown here a perfect confirmation of the idea that its motion must have been right and left as you see it in the picture; the upper third of the chimney has fallen south,—the azimuth happens to be north and south in this case,—and the whole chimney had vibrated in a north-south direction and indicates very clearly, as it is perfectly free to vibrate in any direction, the maximum motion of the ground.

This point is also brought out very well by monuments in cemeteries, one of them having tottered over and having been prevented from absolutely falling only by the presence of the others nearby. Another view shows one tilted completely over, and, as these stand on a level plane and are perfectly free to fall in any direction, they give much more valuable indications

Messina—Free surface wave preserved in the stone curb-stone

than the walls of houses as to the direction of the maximum motion. The curve line was beautifully shown in this earthquake to have great strength, and I am showing two examples of this not merely in a vertical but also in the horizontal sense, showing that a round house would be a very valuable form for earthquake construction. You will see by the view of the apse of the Messina cathedral that it has remained intact because of the curve, and the next view will show this in a double sense in which these two curved portions of another lofty church in Messina have remained, whereas all the other parts have fallen to the ground.

During the great earthquake the surface of the ground is thrown into a series of waves precisely like the waves of the sea but having a motion very much more rapid. These are known as free surface waves. In the picture shown you will see how the curbstone became detached from the sidewalk on the one hand and the roadway on the other and was thrown as a ribbon into the form of the surface wave of the earthquake and retained it. This is one of the most interesting pictures which I was able to take for the studying of the earthquake motion also confirming the direction which had been established and forming a very interesting monument of this event.

We come now to this great eruption of Etna of last year. Lest I forget it at the end of the lecture I should like to say that I do not consider that even this has satisfied the volcanic conditions of the mountain. I think we may look for still more and possibly a still greater activity of Mt. Etna in the future, probably in the near future, possibly in three or four years. About two weeks ago the papers had accounts of some activity of the

General View of Central Crater of Etna

mountain. This, however, was nothing but a little explosive phase in the main crater; it was not a real eruption at all.

You will notice at once the resemblance between the line of eruptive mouths of the 1910 eruption and that of the eruption of 1908. There is an absence of the cones which generally form around these mouths and you will have some idea of the length of the fissure when I tell you that it is a mile and a quarter in its total extension. I should like to relate a fact which proves the necessity of visiting and dwelling upon the volcano during eruption in order to have a faithful idea of what takes place. Any geologist or volcanologist, on visiting this volcano after its eruption, would have declared that one particular crater of this kind had been the least important of all the twenty-four and he would have inferred this from the fact that there was nothing at all lying about in this vicinity, there was no volcanic ash around the craters, there were no bombs of lava lying about nor fragmentary ejecta, and he would have concluded that that particular vent had been probably the least important of all the series. Nevertheless, I, who was there and who lived there throughout the eruption, know that that particular one was by far the most terrible of all the twenty-four; so much so that I had christened it the "Demon." It was the source of all those heavy explosions which shook the mountain and which almost shook us out of our bed in the little hut where we lived. This crater had nothing around it, nothing lay about the orifice for the very reason that its explosions were so strong that everything was thrown to a great distance. And it was important in this case to know that that particular crater had shown the greatest volcanic activity because we could locate by that a position of greatest opening along the whole line of this fissure.

The little hut where I took up my quarters (Page 71) was built by the Italian Alpine Club as a refuge in going up the mountain and for the mounting of certain instruments which have long since fallen into disuse, and when I arrived at Catania from Naples this hut was re-

Alpine Club Refuge near the principal crater where Mr. Perret made his headquarters for two weeks

ported destroyed. But I saw at once that it was still there, and I made a trip up there the first day of my arrival to see if it was practicable to live there and make observations. I found that it was, and with a guide I made this my home for two weeks. It was a most interesting place I can assure you. The lava, which, as I said, flowed at the speed of eleven miles an hour, passed the house at a distance of about 150 yards. The crater had the bad habit of shooting in our direction. It was an inclined mouth and in the absence of contrary wind everything came our way.

It is difficult to give an idea of what life is like under these circumstances. Most people think of the danger and think how terrifying it must be to live there in such a place, but I can assure you that that is probably the very last of all things to be considered. The present discomforts and suffering are so great that any possible danger sinks into significance and is rarely thought of. You will realize at once that to make observations on the edge of this lava stream for several hours exposes one to intense heat, almost enough to scorch the face, in fact, the face becomes burned as by the sun. Then to return to this little hut one had to go through snow ten feet deep and then sleep under many blankets, and with all one's clothing on including a fur cap. Then the gases which arise from the lava are intensely irritating. They consist of hydrochloric acid gas, some free chlorine and a great deal of sulphurous acid, and the irritation of the mucus membrane of the nose and to the bronchial tubes is so intense that I give you my word it was impossible to sleep for the pain after spending two or three hours at the shore of this lava stream. The ashes, so called, are so fine that they enter the eyes, the nose and the ears and are extremely irritating, and I may say that I am not yet healed of some of the burns received from these ashes and gases.

The crater in action did not give one explosion and then another explosion, but it was a perfectly continuous perform-

ance, and the noise was not that of explosions but was something like a continuous banging of a gigantic gong; the noise was purely metallic and continuous, and the lava was thrown up by the ebullition of the gases on reaching the surface to a height of about 150 feet.

My only regret is that I did not have a moving picture machine on hand at this time.

You all know how the smoke-stack of a locomotive can throw out rings, you all know how a cannon can sometimes do

Explosive Emission of Lava—The black spots are masses of molten lava

this; the formation of smoke rings is nothing new, and it is very easy to produce them with a box filled with smoke, the box having a round hole in the top, by tapping it with your fingers,—every smoker knows how to make them with his mouth,—and it is not surprising that a crater which is circular and full of vapor should, when a sharp explosion occurs, emit these vapor rings. I have often seen these at Vesuvius, but never had an opportunity of photographing them because they were usually so delicate and filmy that they scarcely showed upon the plates. In the case of Etna, however, there was so much dense vapor that the most beautiful rings were thrown off from this crater, and floated upward a mile or more into the air, and consequently could very easily be photographed

The view of the smoke ring (Page 74) is taken with the camera pointed almost straight up, and the ring is probably about a quarter of a mile in diameter.

The activity of this lower crater, the lowest vent, soon formed a large cone, and it is very interesting to note the Monte Somma formation so familiar to you professors. The great activity at the beginning of the outbreak formed the cone on the right, after which the weaker action formed a smaller cone inside the larger. One has only to look at the moon with a good field glass to see this produced in a large number of cases in the craters of the moon, and Vesuvius and Etna and almost all volcanoes show this in some degree. I was very much interested to notice recently at the bottom of the crater of Vesuvius that a small vent had opened with this same formation reproduced on a tiny scale not more than six feet in diameter. What was the outer crater resulted from the first activity, after which a small cone grew up in the center. In this case you will see what I just spoke of. You will see here the ring of the outer crater and the smaller cone inside of it; and another view shows you the upper portion of this great stream of lava. From the smoothness of its surface, you will have some impression of its liquidity. It flowed, as I say, at the rate of 16 meters to the second, yet it was so dense, that is to say, its viscosity was so great that it differed very largely from the lavas which I had previously seen from Vesuvius. In the case of the Vesuvian lava, with the same apparent temperature and the same speed of emission, the lava was very soft, its viscosity was very low. In this case on Etna it was impossible to push an iron rod into the surface, so dense was the medium. It is quite impossible with lava of this kind to form those famous medallions which are made constantly at Vesuvius when lava is flowing and which are sold to tourists. Many

Post-eruption view of the principal Crater of the 1910 Eruption

theories have been advanced to account for this difference because the difference in this case is not that of acidity. The grade of acidity of Vesuvius lava and Etna lava is not greatly different. All are in the neighborhood of from 44 to 49 per cent. of silica. They are both basic lavas and the difference in viscosity seems to be due to the difference in soda and potash content. This is a point which it is hoped will be elucidated in the near future.

It was difficult to make proper night views because of the impossibility of fixing the images by a snap shot. Nevertheless, some pictures were obtained when the incandescence of the lava was just beginning to be visible. The cloud of gases is seen flowing off to the right, and the cascade of lava from the upper portion of this cone which I shall explain later is seen coming down the side of the cone and then forms the upper portion of the river. As darkness increased the glow became brighter. A true night picture is now before you (Page 75). This crater is the side of the cone and a most interesting and important thing developed by our being up there at this time. Looking into this opening I thought I could see flames shooting up from the surface of the lava, up through the chimney towards the top. As this has been made an important point by the old writers on Vesuvius, most people have thought that flames were an essential part of volcanic eruptions. Nevertheless, modern geologists and volcanologists have generally come to the conclusion that these flames existed only in the imagination of previous observers. Therefore, I was very doubtful about believing my eyes in thinking that I saw flames inside of this chimney, but later on, when the lava had worked itself up by the consolidation of its bed to the top part of the cone, then flames, true flames of burning gases, shot out from the top to a height of from ten to fifteen feet. Now, this was a most wonderful opportunity for determining the nature of that gas and the opportunity was lost. It was lost for the lack of proper instruments. Nothing was on hand on the spot but a pocket spectroscope, and anybody who knows anything about spectroscopy will know the impossibility of focusing with a pocket spectroscope upon these flames in all

that glare of the lava. To bring up the big telescope with the spectroscope attached from Catania did not at first seem feasible, and this was not done at the time. Afterwards the flames reappeared and the telescope was brought up but before it could be put into use the flames had again disappeared and the opportunity was lost.

Vapor ring from Etna a quarter of a mile in diameter

As regards their color they were simply flame color, and no information could be gained from this as to their nature. They may well have been hydrogen as it is probable that there were traces of hydrocarbon which would give the color and luminosity they had. Hydrocarbons were found in a form resembling vaseline or paraffine in the ashes by Friedlaender. They have been found by Brun at Vesuvius and it is becoming increasingly probable that the hydrocarbons have some function in volcanic action. This is a point which yet remains to be solved by volcanologists.

It was difficult, as I say, if not impossible, to give any idea photographically of the details of the flowing lava at night. The surface of the stream was covered with detail, and I tried very hard to reproduce it; the only way I could approximate it was by photographing in daylight one of these large boulders which was carried down by the stream. This was left upon the banks of the stream by an overflow, and the outside of the surface was preserved, and in order to give some idea of what this looked like at night, I have simply reversed the picture and have made a lantern slide from the positive, and in this way you get some idea of the detail of the surface of the incandescent lava.

These blocks, these boulders which were brought out from the interior of the mountain by the lava stream, were very interesting to watch. They tended to sink in the lava stream; they were incandescent throughout their mass and were soft and pasty like; still they held together. We could get some idea of the depth of this lava stream by watching these boulders. Of course, when they came to a shallow portion of the stream, they would be lifted above the surface, roll slowly on their axes, and then when the stream got deeper they would sink below the surface. As we could measure approximately the diameter of the boulders as they floated past, we in this way formed some idea of the depth of the stream in some points. When the average depth would be perhaps from six to eight feet in places, this would be reduced to four feet, five feet,

Night view of lava stream near point of emission

and in other places it was certainly deeper than twelve feet.

Looking down from the fissure over the lava from the other side, one sees its course down the mountain side until it flows between two cones which are old craters. The streams in the foreground are merely the first outflows over the end of the fissure during the eruption.

One of the most imposing sights of this eruption was down below where the lava had spread out to a width of nearly a mile. On the edges the cooling of the lava had consolidated it for a long distance and formed a sort of pseudo moraine (Page 77), something like the moraine of the glaciers, but not, of course, of the same type, as this is formed out of its own body. The main part of the stream flowing majestically down the mountain side carried upon its surface these great hummocks formed by the lava being squeezed up through the hardening crust when it came to a narrow point between two hills, like paste out of a tube when the masses of lava would harden and these were being borne along like so many icebergs on the top of the stream. The speed at which they were carried along was about four miles an hour and gave the impression of a number of steamers or battleships floating past.

I made a view after the eruption to show one of these hummocks which was left. The lava here, judging from the trees in the foreground, must be something like eighty or ninety feet in depth. It is not surprising to know that this lava is still hot. The last time I was there, some two months ago, I measured 300 degrees Centigrade at its surface. I was able to measure at one point 1000 degrees Centigrade, and this was the highest temperature I was able to record. At the upper portion of the stream where it issued from the vent, it was quite impossible to use the pyrometer, but from several other tests which were made, it seems to be almost certain that at the upper portion the temperature of the lava was about 1200, possibly 1250 degrees Centigrade. The color at night in this case was a golden yellow, not white, but much brighter than mere red.

In the Alps it is frequently possible to find what are called Alpine mushrooms. Flat stones are carried down by the glaciers and deposited on the snow fields

"Alpine Mushrooms" formed by bombs

and then when the snow has melted away the flat stones remain on a little pedestal of snow which has been protected against melting by the shadow of the stone. In this case (Page 76) we have the formation of Alpine mushrooms by volcanic action. Lava bombs thrown from these craters fall upon the snow and then, as it was spring time, the snow melted down from its former level to this level here, and each bomb was left on its own pedestal of snow. In one place there were several thousands of these in the neighborhood of the craters, so that it was very difficult to find two of them sufficiently isolated from the rest to make a good photograph. This is the case with small bombs which become cooled very rapidly by falling into the snow, but the larger bombs would retain their heat, and, falling into the snow which you see here covered with ashes and therefore invisible, would simply continue on their course down the mountain side, throwing out great clouds of steam from contact with the snow. One of these bombs was thrown out from that crater which I call the "Demon," which looked so harmless after the eruption, and fell over near us. This was about the actual size as you see it here. We chased it down the mountain side for some distance before it stopped. I wanted to get a piece from it before it cooled and then photograph it. As you see even after that long run through the snow the bomb was still soft enough to flatten itself out and sink down like a pumpkin when it got to level ground.

One of the curious things about the lava of this eruption was its tendency to consolidate. You have seen the pseudo moraines at the sides of the stream, and it is not surprising to be told that the stream continuously narrowed itself. To make up for this, it deepened itself by scoring a channel in the incoherent materials of the soil, but it did more than that, it built itself up at the actual point of emission, and I could scarcely believe my eyes when I first noticed this. It seemed impossible that this lava at its high temperature should not even melt

Lava tunnel left exposed

Branch of lava stream invading cultivated ground

away the rock with which it came in contact, instead of which it consolidated itself continuously.

At the beginning of the eruption when I first arrived at this little hut, the vent of the lava consisted of two mouths, both of which sent out a stream which united at the base and then formed a single river which flowed down the mountain. Later on, with the progression of the eruption, the right hand vent became reduced to insignificance, and the lava had formed itself up, built itself up, to the top of the cone over which it flowed in a cascade down the side. This is one of the most remarkable things which I witnessed during this eruption, and I am inclined to think that it was the cause of the extinction of the lava flow at the end. I think that the lava consolidated itself at the sides of the vent until the vent was practically choked. Certainly, this would not have occurred, I am willing to admit, if the full supply of lava at high temperature had continued. It certainly was due to a diminution of the supply, but it was a most remarkable thing to see this vent build itself up to the top of a high cone and reduce itself to a mere dribble over the edge.

One of the most interesting and marvelous things of this eruption, and one which has taught me a great deal about the internal workings of such eruptions is this lava tunnel. It is a work of nature which I think you will agree with me is remarkably perfect, this arch being as uniform as could be chiseled by the hand of man. The mountain side just above this lowest crater slumped away leaving exposed this tunnel, and this is where the lava flowed inside the mountain before it emerged from the crater which you have seen. I was able to enter this tunnel for a distance of about a hundred feet and to get to a point under the next one of these craters and look up through the central conduit and see the sky.

In this case you will see that the lava after filling this tunnel had subsided finally to the point where it forms the present floor. Inside of this grotto where I was able to go I could see that below this there was still another which I was not able to enter, and the lava, after

flowing through the one shown, had found its way to this lowermost grotto and this has taught me one thing which I think is

Boulder carried by stream

very important, namely, that not all of an eruption is necessarily on the surface.

One of the most interesting things about the Etna eruptions is that after the eruption earthquakes occur at points around its base. I am inclined to think that the lava after flowing out over the surface on the top of the mountain very often finds its way into these abandoned tunnels and flows subterraneously, finding water bearing strata perhaps in the neighborhood of the towns and producing explosions which cause the earthquakes, or else flowing into fissures causes the dislocations which would produce precisely the same effect.

Another thing learned by this tunnel is a very interesting one. On Vesuvius and on every volcano where I have seen lava issuing from the side of a mountain, it has issued from what is called in Italian an oven mouth; that is to say, an arch-shaped opening at the side of the mountain. This arch is evidently nothing but the top portion of just such a tunnel as this. The height of the tunnel shown is about twelve feet at the entrance—inside the height grows rapidly until it is about twenty-five feet from the present floor. Etna and Stromboli and other volcanoes of this type often throw out most beautiful crystals and other formations. Some found by me on Etna and Stromboli are pyroxenes which have a cruciform tendency. Most of them are not more than about half an inch in diameter. There were very few true bombs in this eruption of Etna. The lava thrown out was so impregnated with gas that its rapid expansion rendered the masses spongy and few true bombs were formed. An exception is this one, which was found by me on the side of the lowermost of these craters and which consists of a mass of quartzite crystals merely covered over with a skin of new lava. The presence of quartzite was marked during this eruption, as indeed it usually is in the modern eruptions of Etna.

APPRENTICESHIP SCHOOLS IN CHINA

China is quick to realize the value of special training in connection with important public work and it is interesting to note that in connection with the Ministry of Communications at Pekin, there is a school for training railway officials. The number of students is limited to 350, varying in age from twenty to twenty-five. There are thirty teachers, most of whom are Chinese students educated abroad. The full course is three years and the curriculum includes the Chinese language, drill, geography, history of Chinese railways, mathematics, drawing, chemistry, physics, traffic management, railway bookkeeping, elements of engineering, workshop administration, and railway law.

THE ULTIMATE STRUCTURE OF THINGS

A BRIEF EXPOSITION OF MODERN IDEAS CONCERNING THE CONSTITUTION OF MATTER, IN THE LIGHT OF RECENT DISCOVERY

BY D. F. COMSTOCK

II

Resume

The statements made in the first article may be summarized briefly thus:

All bodies are made up of ultimate particles known as atoms. These atoms exist in nearly one hundred separate species, are ultra-microscopic in size and they show a very definite tendency to form groups known as molecules. The changes called chemical correspond to the rearrangement of the atoms to form new molecules. There is a ceaseless motion of the atoms of all bodies and this is what we call heat. When the violence of the vibration gets too great (*i. e.*, when the temperature gets above a certain point), a solid substance becomes liquid and if the violence still increases the liquid becomes gas.

THE ELECTRON AND ITS RELATION TO THE ATOM.

We are now ready to consider the other fundamental entity, namely the *electron*. To quote from the first article, "all bodies, as we know them, are complex structures composed of small particles called atoms and still smaller particles known as electrons."

So far as we know all electrons are exactly alike. In this respect therefore they differ greatly from atoms which, it will be remembered, exist in nearly a hundred different varieties.

Size.—In size the electron is very much smaller than the atom. The exact size is not known but it has a diameter *about* one one hundred-thousandth of that of an atom. This means that if the average atom be represented by a sphere one hundred yards in diameter, then the electron would be, on the same scale, about the size of a pin head. In other words the Boston Public Library building is not large enough to represent an atom if a pin head is to represent an electron.

Weight.—The electron is far, far heavier *for its size* than the atom. Although the atom is so enormously larger than the electron, the lightest atom, namely that of hydrogen, is only about two-thousand times as heavy as an electron. A short calculation shows therefore that *in proportion to its size* the electron is a million, million times heavier than the atom. In more technical terms, its "density" is this many times greater than the density of the atom.

The inconceivable minuteness of the electron, as well as its enormous "density," may seem to the reader not accustomed to the results of physics, as positively absurd and totally incredible. The dispassionate inquiry of modern physics, however, leads inevitably to these conclusions, and after all it is the business of the scientist to unravel what he can and report what he finds.

Shape and Structure.—Practically nothing is known as to the shape or structure of the electron. There are indications, however, that it is spherical in shape and perfectly symmetrical in every way.

The Two Electricities.—It will be remembered by those whose physics is not too distantly lost in the past that there are two "kinds" of electricity, "positive" and "negative." If a body is charged with electricity of one kind it repels strongly all bodies charged with the same kind and attracts strongly all bodies charged with the opposite kind. In the words of the elementary physics

books "like charges repel each other; unlike charges attract each other." The attraction of unlike charges is the common phenomenon noticed when in cold weather a recently used comb is held near bits of paper or other light objects. It seems probable that most of the phenomena in nature are due, in the last analysis to electric attractions and repulsions.

Both Kinds of Electricity Abundant in all Bodies.—All bodies seem to possess enormous quantities of both positive and negative electricity but usually it is in exactly equal amounts, so that one kind neutralizes completely the effect of the other and no electricity seems to be present. Charging a body with electricity is really then to be considered as merely disturbing this balance by taking away or adding to the body a small amount of one kind of electricity. We shall see later that the electricity added or taken away is always the negative.

Electrons Negatively Charged.—Each electron has a negative charge of electricity on it and this charge, considering the size of the particle, is enormous. Electrons are therefore attracted toward all positive charges of electricity and repel *each other* strongly. Modern research has made it strongly probable that not only have electrons *always* a negative charge but *negative electricity exists only as the charges on electrons.* That is, negative electricity and the electrons are inseparable and the only way to give a body a negative charge is to put electrons on it or in it.

Atoms and Electricity.—Since all bodies are made up of atoms, charging a body with electricity is the same as charging some of its atoms with electricity. Speaking now of "atoms" instead of "bodies," it follows from the above that no *atom* can be charged with negative electricity without putting one or more electrons on it. Each ordinary atom contains a number of electrons and enough positive electricity to exactly balance the negative of the electrons. *The positive electricity never leaves the atom*, whereas the electrons allow themselves to be taken away from or added to the atom with relative ease.

Negative charge "too many" electrons; Positive charge "too few."—Since only negative electricity in the form of electrons is movable, so to speak, an atom can be charged positively only by taking away some of the electrons which it normally possesses. This allows the positive charge of the atom (which it has perpetually) to predominate and produces the same effect as if positive electricity had actually been *added* to it. Thus to put it briefly, an atom contains normally a certain number of electrons and also positive electricity enough to neutralize exactly their negative charges. The atom is then "uncharged." If an electron is added to the atom from the outside there will be more negative electricity than positive and the atom will have "negative charge"; whereas if an electron is taken away from it there will be more positive than negative electricity and the atom will have a "positive charge." Fig. 7 shows two uncharged atoms, Fig. 4, two negatively charged ones and Fig. 5, two positively charged ones. It must be borne carefully in mind that these *are not pictures of atoms.* They are merely symbolic drawings, the black dots representing electrons and the "plus signs" representing the positive charge which is inseparable from the atom.

Attractions and Repulsions.—It follows of course from the laws of electricity, as recalled to the reader in the paragraph headed "The two electricities," that the following statements are true:

(a) Two electrons *repel* each other (See Fig. 1);

(b) An electron is *repelled* from a negatively charged atom (*i. e.*, one which has one electron too many for neutrality). (Fig. 2);

(c) An electron is *attracted* toward a positively charged atom (*i. e.*, one which has one electron too few for neutrality). (Fig. 3);

Fig. 1

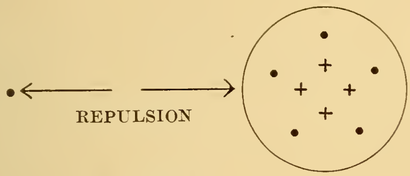


Fig. 2

ELECTRON

Negatively charged Atom (Number of electrons above normal.)

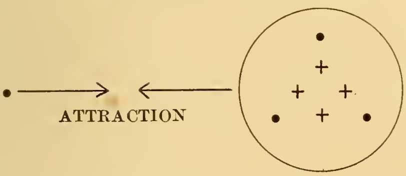


Fig. 3

ELECTRON

Positively charged Atom (Number of electrons below normal.)

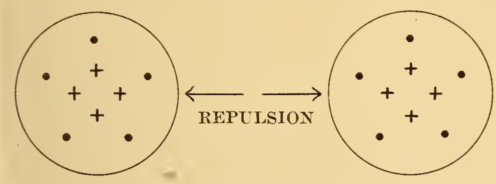


Fig. 4

Negatively charged Atom (Number of electrons above normal.)

Negatively charged Atom (Number of electrons above normal.)

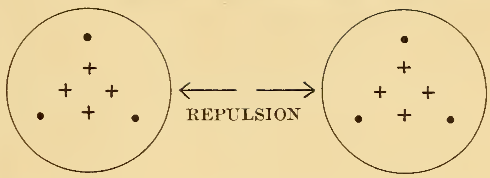


Fig. 5

Positively charged Atom (Number of electrons below normal.)

Positively charged Atom (Number of electrons below normal.)

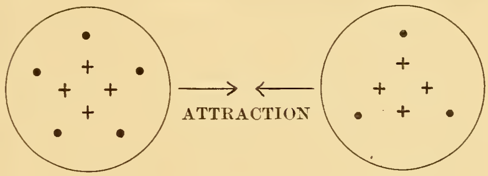


Fig. 6

Negatively charged Atom (Number of electrons above normal.)

Positively charged Atom (Number of electrons below normal.)

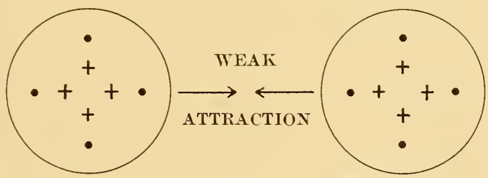


Fig. 7

Neutral Atom (Number of electrons normal.)

Neutral Atom (Number of electrons normal.)

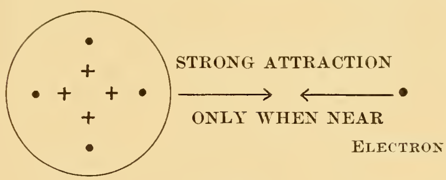


Fig. 8

Neutral Atom (Number of electrons normal.)

(d) Two negatively charged atoms *repel* each other (Fig. 4);

(e) Two positively charged atoms *repel* each other (Fig. 5);

(f) A positively charged atom and a negatively charged atom *attract* each other (Fig. 6).

There are also two attractions of different kind, one of which is already familiar to the reader, which do not follow obviously from the fundamental electrical laws. These are:—

(g) All atoms *attract* each other, even when both are neutral (Fig. 7). This is the familiar attraction dealt with in the first article. It explains the cohesion of solids and liquids in spite of the violent heat vibration to which their

atoms and molecules are subject. This attraction, unlike the common "electrical" attraction (f), is effective only when the two atoms are very near.

(h) All uncharged atoms *attract* electrons. (Fig. 8.) This force, like (g), is only effective when the electron is very near the atom. When it *is* near however the force becomes very great. At greater distances it is very much weaker than the common "electrical" forces before mentioned.

THESE FORCES ALL-EMBRACING.—It is the modern tendency in physics to look upon these attractions and repulsions as fundamentally at the basis of all the physical phenomena of nature. It will be shown later how they promise explanations of chemical affinity, conduction of electricity and other phenomena.

THE ELECTRIC CURRENT.—The attraction which an atom has for an electron varies greatly with the different species of atoms, the so-called metals being substances the atoms of which exert only a relatively weak attraction on electrons.

In a metal therefore it will be relatively easy to move electrons from place to place. When a stream of electrons is caused to move through the body of such a substance we have an electric current. From the modern point of view an electric current in a wire is a stream of electrons moving through the relatively large spaces between the atoms.

The electrons forming the electric current move very slowly, perhaps only several inches a minute. This speed must not be confounded with the so-called "speed of electricity." The enormous "speed of electricity" is due to the fact that the influence is passed on very rapidly from electron to electron, so that when the electrons at the near end of a hundred mile wire are set moving the electrons at the distant end are caused to take up the motion a very small fraction of a second later.

In a few words we can say that the actual speed of the electrons is very slow, but the rate of speed of this influence from electron to electron is marvelously rapid. As an example from every day life, suppose I pull on one end of a very long rope, the other end will move almost immediately so that the *influence* travels with great speed. The rope itself, however, may move very slowly.

In the electrical case, the *influence* travels with the speed of light, *i. e.*, one hundred and eighty-six thousand miles a second, whereas the electrons themselves (*i. e.*, the true electricity) move only a few inches a minute.

STAR PHOTOGRAPHY

ON Friday, March 24th, Professor George W. Ritchey of the Mt. Wilson Solar Observatory, Pasadena, California, will lecture before the Society of Arts on "Recent Astronomical Photography with the Sixty Inch Reflecting Telescope."

Professor Ritchey has for many years devoted himself not only to the design and construction of reflecting telescopes but also to their application to celestial photography. He is a recognized expert in this field of work. The reflector of the Yerkes Observatory and the mirrors of the Snow telescope now set up at Mt. Wilson have both been constructed by him. His latest and greatest achievement has been the construction of the sixty inch reflector now mounted at the Mt. Wilson Solar Observatory, Pasadena, of which Professor George E. Hale is the director.

The lecture will be richly illustrated with lantern slides and will describe the method of constructing the above mentioned sixty inch reflecting photographic telescope, as well as some of the superb results in celestial photography which Professor Ritchey has secured during the past two years. His photographs of star clusters and faint nebulae surpass anything of the kind hitherto obtained.

This lecture is open to the public.

A REPORT of Dr. Sedwick's lecture on "Science and Human Welfare" before the Society, February 8th, will appear in a subsequent number of SCIENCE CONSPECTUS.

PURE FOOD AND THE LAW

SOME OF THE RESULTS OF LEGISLATION FOR PURE FOOD AND HOW THE LAWS ARE ENFORCED—SOME INTERESTING STATEMENTS BY AN AUTHORITY

BY A. G. WOODMAN

ALTHOUGH the Federal Food and Drugs Act has been in force now for nearly four years certain of its provisions are not widely known, so that a brief discussion of the procedure in enforcing it and the results obtained should possess general interest.

In the first place the Federal food law was in reality the sequel to the regulation providing for the examination of imported foods. Attempts had been made for some time to secure legislation by Congress looking toward the control of food supplies. The opposition to the passage of such legislation was sufficiently strong, however, to defeat the various bills introduced, and it was not until March 3, 1903, that a bill providing for the examination of imported foods was passed as a clause in the general appropriation bill for the Department of Agriculture.

The enforcement of this legislation was entrusted to the Bureau of Chemistry and at a subsequent date, in order to facilitate the examinations, laboratories were established at the principal ports of entry, viz.: New York, Boston, San Francisco, Philadelphia and New Orleans. Of these the laboratory at New York is by far the largest in volume of work, and Boston stands next.

Every shipment of food products must pass by invoice at least through the food laboratory at the port of entry. In some cases a sample of the product is taken for analysis; in other instances a simple inspection of the goods while on the examination floor may be all that is required, as would be the case with the proper labeling of a shipment of canned peas; it may be that no sample of the particular shipment or line of goods is required. When a sample is taken the importer is notified that the shipment should be held intact until the examination is finished, which may be a matter of several days. If the goods are found upon examination not to comply with the law the collector of customs is notified and the goods must be returned to the customs warehouse. The importer is notified of the result of the analysis and assigned a date for a hearing at the laboratory, usually at the end of two weeks. In the meantime a portion of the sample is forwarded to Washington for a duplicate analysis in order that a report may be returned before the date of the hearing.

In the case of foods which conflict with the regulations, if no evidence has been adduced at the hearing to warrant any change in the customary procedure there are several distinct courses open to the food officials. If the case is the first of its kind, for instance, or there seems to exist a reasonable doubt as to whether the importer has had sufficient notice in regard to the regulations, a warning that future importations must comply with the law may be the only action taken. This action is comparatively rare at present, because the law has been in force for a sufficiently long time for all directly concerned to become familiar with its requirements. In another case it may be that the goods are misbranded in some way and if properly labeled would comply with the regulations. In these instances it is often permissible to have the goods relabeled under the supervision of the customs authorities. In certain cases where the adulteration is of such a nature that it cannot be corrected by a slight change in the character of the food product or by altering the label it is required that the goods

be reshipped. If such adulterated foods are not removed from the jurisdiction of the United States within a specified time the collector of customs is authorized to seize and destroy them.

It did not require an extended experience in the practical enforcement of these regulations to show that while they brought about a decided improvement in the character of imported foods they did not go far enough. The need for Federal supervision of the goods after they reached this country and were distributed was evident. An instance or two will show more specifically this need. In one case a consignment of olive oil was shown to contain about 20 per cent. of peanut oil and the importers were notified that in future shipments the latter ingredient should be omitted. In a shipment arriving several months later it was found that the olive oil was genuine, but that every four barrels of olive oil were accompanied by a barrel of peanut oil. The intention of the importer is sufficiently obvious. Another case in point was that of a broker who offered for import five tons of ground olive stones, which were declared to be for use as chicken feed. Although it was known that the consignee in this instance did not deal at all in chicken feed, the shipment could not be rejected since it was exactly as labeled. Within a few months, of nine samples of the drugs distributed by the importer in question five were found to contain large quantities of ground olive stones. Could there be much doubt that these belonged to the lot imported previously?

These instances show plainly the need of legislation which would permit the goods being followed into consumption. This formed, as a matter of fact, one of the strongest arguments for the passage of the act passed June 30, 1906, and popularly known as the Pure Food Law. The demand for such a law is voiced in decided manner by a writer at that time. He says: "Counterfeiters of money are restrained, violators of the internal revenue laws are held in check, pirates are summarily disposed of, but those who counterfeit food and drugs, violate state laws and bring dishonor upon the country by pirating the reputation and trade of honest goods are allowed to continue for lack of a Federal law."

The act of June 30, 1906, controls absolutely the manufacture and sale of adulterated foods in the territories and the District of Columbia. Its widest field, however, lies in the fact that it regulates the sale or shipment to sell from one state to another or into or from the country. The administration of the new law, as in the case of the imported foods, was intrusted to the Secretary of Agriculture and practically all the work is done under the direction of the Bureau of Chemistry. Over twenty laboratories have been established in various parts of the country to further the work and an efficient system of inspection, analysis and control has been put in operation. The procedure in the collection and examination of the interstate samples is not essentially different from that of the imported foods just described. Samples are collected by the authorized inspectors. These are examined chemically, and if necessary bacteriologically, and in the case of adulterated samples the analysis is made also at another laboratory in order to confirm the first finding. Reports are made to the Board of Food and Drug Inspection in Washington, and at their discretion cases are referred to the Department of Justice for prosecution in the Federal courts.

In carrying out the provisions of the act the services of trained chemists and especially of those conversant with the special methods of food analysis were, of course, absolutely essential, and it is gratifying to note in this connection the large share that the Institute of Technology has had in this constructive problem. From the very beginning the food laboratory has been in close touch with the development of the work and its students and graduates have taken an active part in the necessary labor of improving and devising methods of food examination, of determining standards of purity and in the varied processes of enforcing the new law. Several of the

newly-established laboratories are in charge of Institute men and numerous others are engaged in all branches of the administrative work from making the collection and analysis of the sample to the final appearance in the courts.

The act is very comprehensive in its scope, covering, in the case of foods, all articles used as food, drink, confectionery or condiment by man or other animals. Under the term "drugs" are included all medicines or preparations recognized in the United States Pharmacopœia or National Formulary, internal or external, for man or animals, or any mixture for the prevention, cure or mitigation of disease. It forbids definitely all forms of false labeling or misstatements. Several of the important provisions of the act have not been entirely or correctly understood by the general public. Prominent among these is the so-called "guarantee clause." This clause provides in effect that the dealer who purchases his goods under a guarantee from the manufacturer shall be exempt from any liability under the act in case the goods are found to be adulterated, but that the action shall be brought directly against the guarantor. This guarantee is secured by a statement placed on the package of food that it is "Guaranteed under the Food and Drugs Act," accompanied by the serial number of the guarantee filed with the Department of Agriculture. This statement, contrary to a rather prevalent belief, is no guarantee of the purity of the food nor does it imply that the government certifies its freedom from adulteration. So widespread has become the opposite impression, however, that it has been found necessary to change the form of this guarantee legend to read "Guaranteed by Blank & Co. under the Food and Drugs Act."

There is nothing in the act which requires that the formula or composition of proprietary foods or remedies shall be placed upon the package, although many persons have the impression that it is so. It is required that the presence and amount of certain powerful or dangerous drugs, as alcohol, cocaine, morphine and others shall be stated clearly upon the container, but this applies only to drugs, not to foods, and beyond this the formula need not be given. Neither is it required that the weight or volume shall be stated. In both of these cases, however, if the formula or the weight or volume *is* stated it must be the correct one in each case, otherwise the package is misbranded.

The use of preservative chemicals in food is in general forbidden. A notable exception to this ruling is the use of external preservatives necessarily removed in the process of preparing the food for consumption, and the use for the present of sodium benzoate in quantities not exceeding one tenth of one per cent., which following the decision of the referee board of chemists, is permissible. The use of coal-tar colors, with the exception of seven definitely stated shades, is forbidden, and these permissible colors can be used only when properly prepared and certified. The presence of artificial color must be declared in any event.

It is provided in the act that the results of prosecutions shall be published, and this is done in the "Notices of Judgment" issued from time to time. Over 600 of these have been issued up to the present and an inspection of them will show clearly the character of the offences for which prosecutions have been brought. It is rather striking to see the number of cases in which the action of the officials has been taken on account of short weight or measure. These cases which are nothing more nor less than simple cheating or dishonesty are surprisingly numerous. The other principal classes of adulteration which go to make up the greater bulk of the indictments are for the sale of decomposed or unwholesome food, patent and fake medicines, "cures" and the like. These are usually found to be misbranded rather than actually dangerous, articles for which the most extravagant claims are made and which bring a high price being found in many instances to be composed of entirely worthless ingredients. Sometimes the reverse is true, as in the case of a teething

syrup for which the claim was made that it was absolutely free from any harmful ingredient and could be used with safety with the youngest babe, but which on examination was found to contain considerable quantities of alcohol, chloroform and morphine.

It is impossible, however, for a fair-minded person to read these accounts of the cases brought without being impressed by the disparity in many cases between the crime and the penalty imposed. A fine of five dollars for the sale of a fraudulent toilet preparation, widely advertised and purchased by trusting consumers all over the country, seems hardly to fit the case. Nor does it seem enough that a firm which deliberately ships into interstate commerce a consignment of frozen eggs far advanced in decomposition should suffer no further punishment than the confiscation of the goods, which they are already well aware should never have been sent out. Many instances illustrating this point might be mentioned were it not that they would extend this paper beyond desirable limits.

When we come finally to see what the Pure Food Law has accomplished in the time that it has been in operation there is evidently much of value. A great deal was brought about even before the act went into operation merely through the silent force of a National law. A majority of the retail dealers were sincerely and cordially in favor of the law; many of the manufacturers advanced the standard of their goods and showed their willingness to deal fairly by the authorities, the retailers and the consumer. The simple enactment of such a statute was sufficient to drive much adulterated and misbranded food from the market. Another general advantage resulting from the new law was the awakening to greater efforts of some of the state officials, and what is of still greater importance, the revival in crystallized form of the movement for the greater uniformity of state legislation regarding foods. The avenues of trade are National, not local, and it is in many ways a commercial absurdity that an article of food should be considered pure in one state and impure in another; that harmful substances should change their nature and become innocuous as they cross the state line; that a truthful label in Texas should become false in Massachusetts. Purity and truth are not supposed to be variable terms. Even its most enthusiastic advocates do not claim that the limit of perfection has been reached in the Federal law, but it is a significant fact that between June 30, 1906, and July, 1907, new general food laws or sweeping amendments to old laws were passed in thirty-two states; that many of the most important provisions of these laws are based upon the National statute.

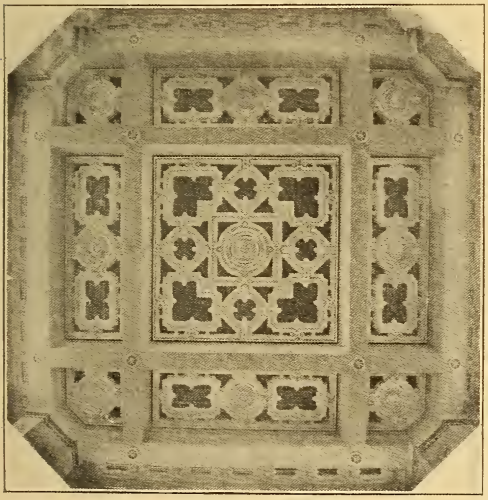
That the Pure Food Law is responsible, on the other hand, for the increase in the price of foods is easily shown to be untrue. It is equally responsible for the increase in the cost of labor, of rent, of clothing. The cause is a more general one. The one exception is possibly in the articles formerly sold in competition with those that were adulterated or misbranded. These bring their normal prices, while the adulterated ones bring less. Neither is the food law responsible for the increase in the price of milk, which is caused by the agitation for clean milk, milk produced under sanitary conditions and from non-tuberculous cows.

Finally, then, in the Federal law we have a statute whose terms are broad and comprehensive. It provides against all adulteration, the use of harmful substances and false labeling. It does not attempt to legislate on scientific questions, but leaves such questions for scientific determination and regulation. It provides opportunity for the injured party to be heard in defence of his products before court proceedings or seizure. It provides a means for coöperation between National and state officials by requiring the National authority administering the law to examine and report upon any specimen of food submitted by the health officer of any state. It is the only present basis for uniformity on this subject throughout the various states. What is still needed most of

all, however, is a greater respect for this and other laws on the part of producer and seller. We need a more sensitive public conscience. It is necessary that the bulk of intelligent people shall take time to consider these things and to uphold the public officials who are endeavoring in the face of a determined and at times strenuous opposition to enforce the rights of the long-suffering consumer.

A NEW EPOCH IN ARCHITECTURAL LIGHTING

A PAPER recently presented by Bassett Jones, Jr., graduate of the Institute of Technology in the course of electrical engineering, marks what must be considered a new epoch in the history of electric lighting according to the *Electrical World*. This is probably the first



example in which the full resources of the illuminating engineer have been marshalled to aid the electrician in carrying out his designs.

Mr. Jones made the illumination the fundamental part of the decorative scheme. To do this he freely resorted to indirect lighting and employed both colored screens and colored illuminants. To apply colored lights harmoniously, requires the solution of some knotty problems in light diffusion. The building treated was the Allegheny County (Pa.) Soldiers' Memorial.

The treatment of the ceiling of the main auditorium concentrates around the light centers which are also architectural centers when the room is lighted by daylight from without. These centers consist of richly pierced plaster ornament and over these piercings are suspended various forms of electric illuminants with specially shaped reflectors. For a mellow golden tone, a combination of tungsten lamps and amber glass was found to be the most efficient source of illumination. Elsewhere yellow flame arcs were employed for decorative effect in combination with nitrogen tubes shedding a pale pinkish glow and with mercury arcs toned to a soft sky-blue by colored glass. The expense of this form of illumination was probably less than with the more conventional form, as the cost of fixtures would have exceeded that of the plan adopted.

The accompanying cut shows one of the ceiling centers.

SUB-SURFACE CAVITIES

IN several cases railroad tunnels have revealed the existence of large caves of which there is no external evidence. These caves or rifts are very large in some cases and seriously interfere with the driving of tunnels. The latest instance of this is in connection with the new railroad line to connect Rome and Naples. A tunnel four and one-third miles long under Mt. Orso struck a deep rift 200 feet wide, apparently decending to the sea level. It will be necessary to go around this cavity and work from the other side. The method by which the road will be carried over the cavity has not yet been decided upon.

PROFESSOR WILSON'S LECTURE FRIDAY

Professor Edmund Beecher Wilson, one of the foremost, if not the very first, of biologists of the United States to-day, is more particularly a cytologist,—*i. e.*, one who studies the phenomena of cell life and individual cells. In his specialty he is brought face to face with the fundamental phenomena of life, both cellular and in the form of complex organisms, and especially with cell multiplication and reproduction.

Professor Wilson's volume entitled, "The Cell in Development and Inheritance" as soon as it appeared became a classic, and has been translated into several Continental European languages.

Of late years Professor Wilson has given special attention to problems of heredity and the genesis and control of sex, and in his lecture on Friday evening, he is likely to deal in a novel and original way with these most fundamental of all biological subjects.

Professor Wilson is also famous, not only as an original worker, but for a manner of unusual magnetism and charm. He is rightly considered one of the best of living teachers of biology, and some of the most prominent biologists of the day have been trained in his laboratory, and in contact with his stimulating personality. He is very rarely heard in public and his appearance in Huntington Hall on March 3d, will, therefore, afford an unusual opportunity, for which the public are indebted to Professor Wilson's close personal friendship with President Maclaurin.

This lecture is open to the public.

NEW MEMBERS OF THE SOCIETY

At the meeting of the Society of Arts held February 8th the following applicants for membership were presented and elected:

Wm. A. Paine, 82 Devonshire St., Boston, Mass.
Jerome C. Hunsaker, U. S. N., 215 Newbury St., Boston, Mass.
Edmund D. Barbour, 610 Sears Bldg., Boston, Mass.
Sylvester Baxter, 32 Murray Hill Road, Malden, Mass.
Samuel N. Brown, 119 Commonwealth Ave., Boston, Mass.
Myron H. Clark, 7 Glen Rock Circle, Malden, Mass.
Leonidas H. Cress, Brae Burn Country Club, West Newton, Mass.
Frank A. Day, 35 Congress St., Boston, Mass.
Edwin F. Fobes, 3 Chandler St., Lexington, Mass.
Charles W. Hubbard, 55 Congress St., Boston, Mass.
Arthur A. Knights, 100 Beacon St., Worcester, Mass.
Arthur T. Lyman, P. O. Box 1717, Boston, Mass.
Miss Susan Minns, 14 Louisburg Sq., Boston, Mass.
John Wells Morss, 201 Devonshire St., Boston, Mass.
T. F. E. Reardon, Hotel Longfellow, West Lynn, Mass.
Hubert S. Smith, 215 Newbury St., Boston, Mass.
Carl Wachter, 390 Harvard St., Cambridge, Mass.
David L. Webster, 134 Summer St., Boston, Mass.
Henry M. Wheelwright, Union St., Ware, Mass.
Frank W. Kimball, 283 Walnut St., Dedham, Mass.

HUMAN AND BOVINE TUBERCULOSIS

GREAT DANGER IN MILK FROM TUBERCULOUS COWS—OUT OF THREE HUNDRED AND FIFTY-TWO CASES OF TUBERCULOSIS IN CHILDREN ONE-QUARTER WERE OF BOVINE ORIGIN

There has been a great deal of interest shown for a long time with regard to the possibility of tuberculosis of cattle being transmitted to man, and the discovery of recent years that a large proportion of our milk cows are infected with this disease has increased the interest in the problem. In 1882, when Dr. Robert Koch discovered the bacillus of tuberculosis, the unity of tuberculous disease in man and the lower animals was definitely established, and up to 1901 there was a steady growth in the belief that the disease could be transmitted from beast to man. The reason for the change of belief that occurred at this time was primarily due to a statement made by Dr. Koch himself, in which he doubted very seriously the susceptibility of human beings to bovine tuberculosis, and he even stated that it was his belief that no special protective measures were indicated. Since that time many private and public investigations have been made in order to settle the question and prove either one way or the other with regard to the transmission of disease from animal to man.

The most direct method of experimentation would have been to have inoculated human beings with the germs of bovine tuberculosis, but, of course, this method was not permissible. Dr. Theobald Smith in 1896 and 1898 published papers in which he pointed out certain characteristics of the germs of human and bovine tuberculosis which gave evidence that there were differences existing between them. There are now recognized distinct types of human and bovine tubercle bacilli. The differences are based on certain cultural and virulence variations, the word "cultural" being used in its bacteriological sense, that is, in connection with the cultures of the organism grown in the laboratory under suitable conditions. This method of differentiation received little attention until the question took on new importance as a result of Koch's startling statements already referred to.

Since then it has been the basis of a great deal of investigation, and an important paper by Doctors William H. Park and Charles Krumwiede, Jr., in the *Journal of Medical Research* for October, 1910, on "The Relative Importance of the Bovine and Human Types of the Tubercle Bacilli in the Different Forms of Human Tuberculosis" makes use of these methods of differentiation. These investigators made a remarkable study into the problem and conclude that tubercle bacilli as isolated from man fall into two groups, and that "one of these groups is identical in all its characters with that found in cattle."

In this research they have made a special study of 436 cases of human tuberculosis, from which they have isolated in each instance the germ causing the disease. Furthermore they have selected their cases at random and have not made any special effort to get cases in which the probability of bovine infection seemed large, as was done by most of the previous investigators. They wished to find out by this means the amount of tuberculosis that could actually be considered of bovine origin. Of the 436 cases, 291 were pulmonary tuberculosis, or consumption, and in none of these were they able to discover tubercle bacilli with bovine characteristics. In 297 cases of all kinds of tuberculosis in adults, they were only able to find the bovine tubercle bacillus once, this being in a case of tuberculosis of the genito-urinary system. In

54 cases examined of children between the ages of five to sixteen they were successful in finding the bovine organism on nine occasions, and in 84 cases of children under five years of age they were able to find this organism twenty-two times. As is well known, tuberculosis in children and infants is mostly confined to the glands of the neck, the membranes of the brain, the bones and joints, although generalized tuberculosis is frequently met with.

In a special table of 50 fatal cases in children under five, they show that 9, or 15 per cent., had an infection of the bovine type. Besides their own observations, they have collected the investigations of various foreign observers who have also isolated the tubercle bacillus from each case and studied it to determine whether of the human or bovine type. In all they have collected 606 cases, to which they have added their own, 436, making a total of 1,042 cases studied. Of this number, 686 were cases in adults, and only 1.3 per cent. of them were of bovine origin. One hundred and thirty-two were cases in children from five to sixteen years old, and 25.0 per cent. of these showed infection with bovine tubercle bacilli, while in 220 cases of children under five, 26.8 per cent. were found to be caused by the bovine type of organism. In 4 cases both types of organisms were found.

This splendid piece of work emphasizes, then, the danger that children run in drinking the milk of tuberculous cattle. It also proves conclusively that adults rarely are able to contract the disease from milk or its products. This investigation should be of great assistance to public health authorities in their demand that all milk sold within the limits of their jurisdiction shall come, either from animals which have been tested and proven free from tuberculosis, or shall be pasteurized so that any germs of this kind which might be present would be killed and the milk thus rendered a safe food for all. S. M. G.

The fiftieth anniversary of the granting of the charter to the Institute of Technology will be commemorated April 10.

GREAT TRANSATLANTIC LINERS

During the past year the readers of the newspapers have been frequently astonished by the announcements of new ocean liners ever increasing in length, capacity and speed. The "Lusitania" and "Mauretania" are the giants of yesterday with a length of 790 feet and a displacement of 40,000 tons. The "Olympic," launched last year, is nearly 100 feet longer than these, or 882½ feet, with a displacement of 60,000 tons, and the "Europa," the new boat of the Hamburg-American Line, will be 900 feet in length and will have a displacement of 65,000 tons. The "Olympic" and her sister ship, the "Teutonic," will have a speed of 21 knots and the "Europa," 21½ or 22 knots. The Cunard Steamship Co. have announced that they will build a ship of the same general class but speedier with a length of 855 feet.

The size of ocean-going steamships is now limited by the length of the piers and the depth of the harbors. These immense vessels will tax the facilities of the New York docks. A strong effort is being made to induce the War Department to allow the extension of the piers further into the Hudson River. In a speech recently made by Admiral Bowles of the Fore River Shipbuilding Co., he stated that he expected to see vessels 1,000 feet in length.

THE ATLANTIC COAST CANAL

A vast enterprise designed to improve the waterways of the United States is a plan known as the Atlantic Coast canal which is contemplated by act of Congress and which if carried out will afford an inland waterway paralleling the Atlantic sea coast from Boston, Mass., to Key West, Florida. The Cape Cod Canal which is a part of the scheme is now in progress of construction. It will be four miles long across the neck of Cape Cod.

An estimate has recently been made for the section of a canal extending from New York to Philadelphia, which will cost about $40,000,000.

COLLOIDS AND COLLOIDAL SOLUTIONS

AN INTERESTING GROUP OF SUBSTANCES THE STUDY OF WHICH HAS OPENED UP A NEW FIELD IN SCIENCE AND IN THE ARTS

BY ELWOOD B. SPEAR

If we stir sugar into a cup of water we make what the scientist calls a solution. It is a homogeneous mixture of water and sugar, that is to say, the smallest portion of the liquid that we can see even under the most powerful microscope contains relatively the same amount of sugar and water as any other portion of the solution. According to the modern theories of the constitution of matter, both water and sugar are present as molecules. (See SCIENCE CONSPECTUS, page 50.) These molecules are too small to be seen by the eye even aided by the microscope, and the whole solution, therefore, appears to us to be made up of only one substance. Solutions where the single molecules of the dissolved substance move freely about among the molecules of the solvent are called crystalloid solutions, and the dissolved substance is called a crystalloid. These solutions may be colorless like white sugar dissolved in water or colored like strong tea, but they are always clear and more or less transparent.

COLLOIDAL SUSPENSION. — The water in our rivers and streams in early spring is almost always turbid. This is due to the fact that it contains large quantities of mud and other substances that are divided into very small particles. These particles are held in suspension by the water because their weight is so nearly equal to that of the same volume of water that the whole mass must remain quiet before the mud particles can settle down to the bottom. If the water is moving, the mud particles are carried along with it, and the settling out is prevented by the mixing action of the running water.

If muddy water is allowed to stand, we notice that the largest particles fall out in a few minutes, while it usually takes hours before the water is clear of all the very small particles. This is a general law that for a very finely divided substance suspended in a liquid the larger the particles, the faster they will fall to the bottom. It is possible to obtain particles so small that they do not fall out for several months, and these particles have been given the name of "colloids," while the whole solution is called a "colloidal suspension."

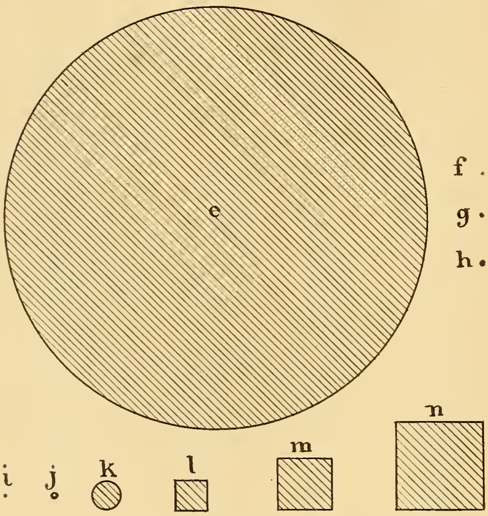
Some of these colloidal particles contain a few, some of them many hundreds of molecules of the dissolved substance. Each particle forms a single community in the liquid and moves as a whole, just as eleven individual players form a football team and make a concerted attack on the opponent's goal, or a thousand soldiers form a regiment and charge a fort.

Colloidal suspensions can be made of many metals, such as iron, silver, gold and platinum, by allowing an electric current to jump across through water between the points of two wires of the metal in question. The particles of a colloidal suspension of platinum made by this process are of various sizes, some of them large enough to be seen with the unaided eye, while others are not much larger than water molecules. Some of the large particles fall out in a few hours, while the extremely small ones may remain suspended in the water for years.

SIZE OF COLLOIDAL PARTICLES. — Suppose one of these particles and the head of a pin were each enlarged in the same proportion until the particles could be seen by the human eye, the head of the pin would then appear as a huge mass of metal as large as a seven-story building.

TRUE COLLOIDS. — If we attempt to dissolve a small piece of jelly in warm water we obtain a solution that appears to be clear. In reality the molecules of the jelly are not single and independent

of each other, but have formed groups of two's, three's, ten's, etc., like school children at intermission. We have made here a true colloidal *solution*, which differs from colloidal suspensions chiefly in the fact that particles are soft and plastic, resembling jelly, soap, rubber, etc., while those of the *suspensions* are much harder, like tiny pieces of metal.



In the above figure, e represents a blood corpuscle enlarged 7,000 times, and f, g and h the comparative size of the particles in a colloidal suspension of gold. Now consider that f, g and h are enlarged to l, m and n, then i, j and k will represent the comparative size of molecules of alcohol, chloroform and starch, respectively

Blood a Colloidal Solution. —Most people imagine that the blood is a solution like red ink where every portion of the liquid, however small, is the same color. In point of fact, however, the red color is due to the presence of innumerable small red particles called corpuscles, floating about in a waterlike liquid. These are large enough to be seen by a powerful microscope. In addition to the red particles there is also a considerable number of white corpuscles present in the blood.

Milk. — Milk also is a most interesting colloidal solution containing yellow and white particles. If milk is allowed to stand, the yellow particles unite and float on top, and we call them cream. When the milk sours the white particles unite and we get thick milk. Cream, however, contains both white and yellow particles, because when it is churned we get the yellow particles in the form of butter, while the white ones remain in the buttermilk. If now the buttermilk is allowed to stand, we find that the white particles have united and fallen to the bottom, while the clear amber-colored liquid is left on top.

Colloidal Particles Grow. — The colloidal particles of a gold solution may be caused to unite together and grow larger by violent stirring, just as churning will gather the yellow particles of cream to form solid butter. This uniting of the colloids to form larger particles is called " coagulation," and is produced most easily by violently stirring a hot solution. Some of our readers will remember in boyhood days when obliged to churn how delighted they were when the cream became too warm, because the butter came faster; in other words, the heat had done a part of the churning.

The reason that the flow of blood from a wound can be stopped is because the red particles under the action of the air unite or coagulate and stop up the wound and thus prevent a further loss of blood. This is spoken of as the " clotting " of blood.

More interesting properties of these colloidal solutions will be dealt with in a later number of Science Conspectus.

RADIUM BANKS

The price of radium has been stated by Sir William Ramsay to be $2,100,000 an ounce, about $400,000 less than the value given by him a year ago. At that time there was said to be only a quarter of a pound of radium in the world. In Paris and London, radium banks have been established for the purpose of renting radium.

DESTRUCTION OF BACTERIA IN WATER

SOME NEW APPLICATIONS OF ULTRAVIOLET LIGHT POINTING TO ITS ULTIMATE SUCCESSFUL USE IN PRACTICAL WATER STERILIZATION

BY M. R. SCHARFF

WITHIN the past few years, in response to a demand for a simple, direct and economical method of removing the bacteria from potable waters, the practical sterilization of water has received much attention. Many chemical methods, based on the addition of chlorine, ozone, or other substances have been devised, but none of these is entirely free from the objection that there is a strong popular prejudice against the addition of any chemical to drinking water. Recently the attempt has been made to sterilize water simply by exposure to ultraviolet rays; this process entirely avoids the objection noted above, and as it seems well adapted to making a strong appeal to the popular imagination, its development will be a matter of great interest.

The ultraviolet rays are invisible radiations of the same nature as the visible light rays, but of shorter wave length. In measuring these short wave lengths, the micron, one one-thousandth of a millimeter, is a convenient unit, and the ultraviolet waves measure from about four-tenths of a micron down. Bacteria subjected to their action are destroyed with the greatest rapidity, and all living cells are strongly affected by them. These biological effects have been known for many years, and have been applied therapeutically in the treatment of lupus, ulcers, and other skin lesions, but it is not until within a few years that their applicability to the sterilization of water has been recognized.

Ultraviolet rays may be obtained from various sources. Sunlight contains some of them, but the atmosphere absorbs nearly all before they reach the earth's surface. Other sources of the ultraviolet light are the electric arc, especially when enriched with zinc, aluminum, magnesium, etc., the electric discharge through rarefied gases, as in Crooke's and Geissler tubes, and the mercury vapor arc.

Glass is practically opaque to the short, ultraviolet waves, while quartz transmits them quite readily. It is, therefore, necessary that all apparatus to be penetrated by the ultraviolet rays be made of thin, transparent quartz. Water, too, is opaque unless entirely free from color and suspended matter, and filtration is a necessary preliminary to sterilization whenever this condition does not exist.

During the last three years, a large number of French investigators have been at work on the practical application of this method of sterilization, and their results have been published in a considerable number of communications in the *Comptes Rendus de l'Academie des Sciences,* and in other periodicals. A great many types of apparatus have been devised, and four of them are selected for brief description below.

Courmont and Nogier employed a Kromayer quartz mercury arc lamp, 30 cm. long, suspended at the center of a circular metal tank. They found that water infected with colon or typhoid bacilli could be sterilized completely by this device in one to two minutes, one minute being almost always sufficient. The volume of their tank was about 85 litres and the current used 9 amperes at 135 volts. Assuming the sterilization complete in one minute, the current consumption of this device was about 900 kilowatt hours per million gallons. This, of course, is enormously expensive, for, at ten cents per kilowatt hour (a common rate for lighting current) the current cost would be $90 per million gallons.

Billon-Daugerre has devised a small domestic sterilizer, consisting of a quartz tube containing rarefied hydrogen or sulphur dioxide, placed at the center of a larger glass tube. The water circulates through the annular space between these tubes, and ultraviolet light is produced by the passage through the rarefied gas of the spark from the secondary coil, of a small Ruhmkorff coil. With this apparatus, operating on 2 amperes at 6 volts, he has sterilized completely 5 litres per minute. At this rate the current consumption is about 150 kilowatt hours per million gallons, and the current cost, computed as above, $15 per million gallons.

Henri, Helbronner and de Recklinghauser pointed out that Courmont and Nogier made a mistake in immersing their lamp in water, as the mercury arc lamp depends for its efficiency on the high temperature of the tube and contained gases. They, therefore, tried first suspending the lamp above the water surface by means of floats. Later they improved their apparatus by passing the water through a semi-circular tank, provided with radial baffles, so that the water is brought three times in contact with the walls of the quartz box at the center containing the lamp. In an experimental run at Marseilles, using a Westinghouse-Cooper-Hewitt quartz mercury arc lamp operating on 3 amperes at 220 volts, this apparatus worked successfully day and night for about six weeks, treating 600 cubic meters per twenty-four hours. During this test the raw water varied from 30 to 300 bacteria per cubic centimeter, with 50 to 1,000 colon bacilli per litre, indicating distinct pollution. The treated water averaged one bacterium per cubic centimeter, and no colon bacillus was ever found in one litre. Thus a potable water of the highest character was obtained at a current consumption of about 100 kilowatt hours per million gallons, or at a cost of $10 per million gallons on a ten cent basis.

Urbain, Scal and Feige have devised an interesting and novel apparatus of still another type. Water is pumped tangentially through the side wall of a cylindrical tank with small concentric openings in the bases. The water circulates spirally toward the center, passing out through the bottom opening, and forming at the center a cavity with walls nearly vertical. In this space they place their source of light, an electric arc, the positive electrode of which is an aluminum rod with an iron core. Thus the lamp is placed in the center of the liquid, without being wet by it. With this ingenious device, the inventors report that they have completely sterilized polluted water with a current consumption of about 76 kilowatt hours per million gallons, at a current cost of $7.60 per million gallons.

Even the lowest of these current costs is too high to pay for sterilization, according to American ideas, but the results show that it is possible to sterilize large quantities of water with ultraviolet rays, and there is every reason to hope that with further study great economies in the production and application of the rays may be accomplished, so that this ideal method of sterilization may yet take a place among the practical methods of water purification applicable to American conditions.

TURBINES COMPARED WITH RECIPROCATING ENGINES

In a recent paper read before the Society of Naval Architects and Marine Engineers, Clinton H. Crane presented a valuable comparison of steam and coal consumption with turbines and reciprocating engines. A triple screw, 1,300-ton steam yacht had been fitted with steam turbines which, on trial, failed to fill the guarantee of the makers as to economy, and it was decided to substitute a triple-expansion engine for the middle-screw turbine, the engine to exhaust into the remaining turbines. With the three turbines, thirty-four tons of coal were required to produce thirteen knots over the trial course. With the triple-expansion engine alone this consumption was reduced to 25 tons and to 22.7 tons with the combination of engine and two exhaust turbines.

NEW IDEAS CONCERNING DISINFECTION

EVIDENCE THAT INANIMATE OBJECTS OF THE SICK ROOM SPREAD DISEASE IS VERY SLIGHT—FUMIGATION OF PREMISES ABANDONED IN SOME CITIES

Everyone who has been unfortunate enough to have personal experience with scarlet fever or diphtheria is familiar with the disinfection or fumigation process that is carried out at the termination of each of these diseases. It is interesting to note that in some places this terminal disinfection has been abandoned and apparently without any bad effect, there being no unusual number of secondary cases recorded. Much has been made of fumigation in the past and it is still generally believed that if the Board of Health creates a strong odor by the liberation of either formaldehyde or sulphur dioxide gases in a presumably infected room or dwelling that all danger of further cases is averted.

The science of bacteriology, while even yet an infant science, has been developed a great deal in the past few years and a mass of evidence has been brought forth that disproves largely the long cherished idea that inanimate things are to be classed among the most important bearers of disease germs. It is certainly true that the drinking cup freshly infected with the germs of tuberculosis, the lollypop transferred directly from the mouth of one child to that of another, are examples where inanimate objects are of real importance in spreading disease, but the evidence of infection from rooms that have sheltered infectious diseases or even from things that have been in close contact with the patient, is slight and of small importance. The disease-producing organisms, with a very few exceptions, die rapidly when exposed to the unfavorable environment of the sick room.

The really important factors in the spread of scarlet fever and diphtheria, excluding, of course, the actual infection of milk that sometimes occurs and produces outbreaks of varying size and intensity, are (1) direct contact with the patient or something very recently infected by the patient, (2) unrecognized mild cases which are not put under any restraint and (3) carrier cases. Carrier cases are those in which individuals may be spreading the germs of a specific disease when they themselves do not show any indications of the disease. Sometimes such carriers may have had the disease in question and are completely convalescent, but not infrequently they may never have had any symptoms at all. These carriers are, of course, much more dangerous to the community than if they were actually sick in bed under proper isolation and quarantine.

Carriers have long since been known in the case of diphtheria, and it is extremely probable that when the organism that causes scarlet fever has been discovered, that it will also be proved by bacteriologists to be included in the carrier group.

As a result of a very careful and scientific study into this matter, Dr. Charles V. Chapin, the superintendent of health of Providence, R. I., has abandoned as a regular procedure disinfection after these two diseases. After a trial of several years he is convinced that disinfection is unnecessary. He points out that terminal disinfection does not accomplish anything, but really tends to withdraw attention from the importance of contact infection and the necessity for personal cleanliness.

Dr. Chapin further believes that the money spent for disinfection (New York spent $55,569.41 in 1908 and Boston $20,123.49 in the same year) could be

used to greater advantage in paying the salaries of good visiting nurses, who could "accomplish a world of good in assisting in the care of the sick and instructing by precept and example in the method of cleanliness in the management of contagious disease." Newton, Mass., has similarly recently ceased disinfecting after cases of diphtheria, unless specially requested, and it is extremely probable that the future will see a very general decrease in this common practice.

Dr. Chapin's paper is to be found in the *Journal of the American Public Health Association* for January, 1911.

S. M. G.

ECONOMY IN POWER PLANTS

The question of economy in power plants is a very large one and its details are beyond the intended scope of this magazine. It may, however, not be out of place to point out some of the broad underlying principles. Often the question of the most economical coal to use in the boiler-room is settled upon the basis of the number of heat units in—let us say for convenience—a dollar's worth of coal, this amount being determined by experiment. The real basis for economy is, however, how much water can be evaporated for *one dollar*. The coal that will evaporate the most water for one dollar is the proper one to use for real economy. This question goes far back of how many heat-units there are in a dollar's worth of coal and involves such questions as handling, depreciation, etc. For instance, one coal which may have more heat-units in a dollar's worth than another may actually be more expensive to use because it may require an increase in the boiler-room force to handle it. Or it may ruin the grates, thus entailing an increased charge for depreciation.

Again, a plant of high thermal efficiency may not be as economical to operate as one of lower thermal efficiency. By thermal efficiency is meant the percentage which the useful energy put out by the plant is of the total energy available in the material used as fuel. For instance, a steam plant of perhaps eight per cent. thermal efficiency may be more economical to operate than a Diesel engine plant of twenty-five per cent. efficiency—on account of the possibility of using a cheaper grade of help to operate the machinery, cheaper first cost of plant, cheaper repairs and possibly less depreciation. These questions are broad ones and cannot be settled by considering a single part; the problem must be considered in its entirety.

L. E. M.

FLUORESCENT REINFORCEMENT

Readers of Science Conspectus have often noticed the peculiar green light used for illuminating purposes in factories, government buildings, etc. Although the human countenance looks ghastly in the rays of this light which is lacking in red and orange rays, it is admirably suited for photograph and photo-engraving rooms, machine shops, drawing rooms and certain other work rooms. This is known as the Cooper Hewett mercury vapor lamp, and because it embraces only the rays of the upper half of the spectrum, the violets, blues and greens, many objects illuminated by it assume colors different from their appearance in daylight.

Mr. Hewett has recently made a most important and interesting discovery to the effect that by using a fluorescent reflector the light of this lamp is quickly changed, because the fluorescent reflector contributes the red and orange rays which were lacking in the light itself. With this reflector, the light becomes approximate to daylight and objects resume their normal colors. This discovery is revolutionary in its character as the same principle can be applied to other sources of light. A reflector can be made which will furnish particular rays lacking in other sources of illumination. It is also possible by this method to produce some very beautiful effects in special color lighting.

SCIENCE CONSPECTUS

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THE PHYSICAL BASIS OF HEREDITY

LECTURE DELIVERED BEFORE THE SOCIETY OF ARTS MARCH 3, BY PROFESSOR EDMUND B. WILSON OF COLUMBIA UNIVERSITY

In this address I shall attempt to indicate some of the conclusions that have been reached in regard to the mechanism of heredity in the germ-cells and in other kinds of cells. Heredity might be defined in many ways. For our present purpose we may define it roughly as that process or series of processes whereby plants and animals come to resemble their progenitors—I do not say their parents, because the offspring often resemble them less closely than they do their grandparents or even more remote ancestors. We may think of the characteristics of the individual as due to its mode of development from the egg. Could we discover what it is that determines development from the egg, we should at the same time discover what determines heredity. We thus arrive at an embryological view of heredity; and this view is of great importance for the microscopical investigation of the subject, since such study is largely occupied in practice with the determination of embryological development.

There are two fundamental conclusions in regard to heredity about which the whole study of the problem is now revolving. One is familiar to everyone. It is the fact that every plant or animal which has two parents is by this fact doubly determined in its development. We may accordingly speak of the "hereditary constitution" of such organisms as being double or "duplex," its characters being somehow doubly represented in the apparatus of determination. In pure bred races we do not ordinarily perceive this fact, since both parents are so nearly alike. It comes clearly into view in the case of crosses between parents which differ in some obvious way, a familiar example of which is the cross between the white and the black races of men. The mulatto offspring is brown or yellow, the color obviously being determined by the coöperating influences of the two parents. Again, the cross between white-flowered and red-flowered varieties of the "four-o'clock" (*Mirabilis*) gives offspring with pink flowers, which at once reveal the influence of both parents. In many cases, however, the duplex constitution of the hybrid only appears upon further experiment. For example, a gray mouse or rabbit crossed with white gives hybrids that are not pale gray or spotted but are apparently pure gray. The white *seems* to have disappeared; but when these gray hybrids are bred together some of the offspring are gray and some pure white. Obviously, therefore, the gray hybrids are as truly duplex in respect to color potentiality as is the mulatto, though the white character is temporarily concealed or "dominated" by the gray.

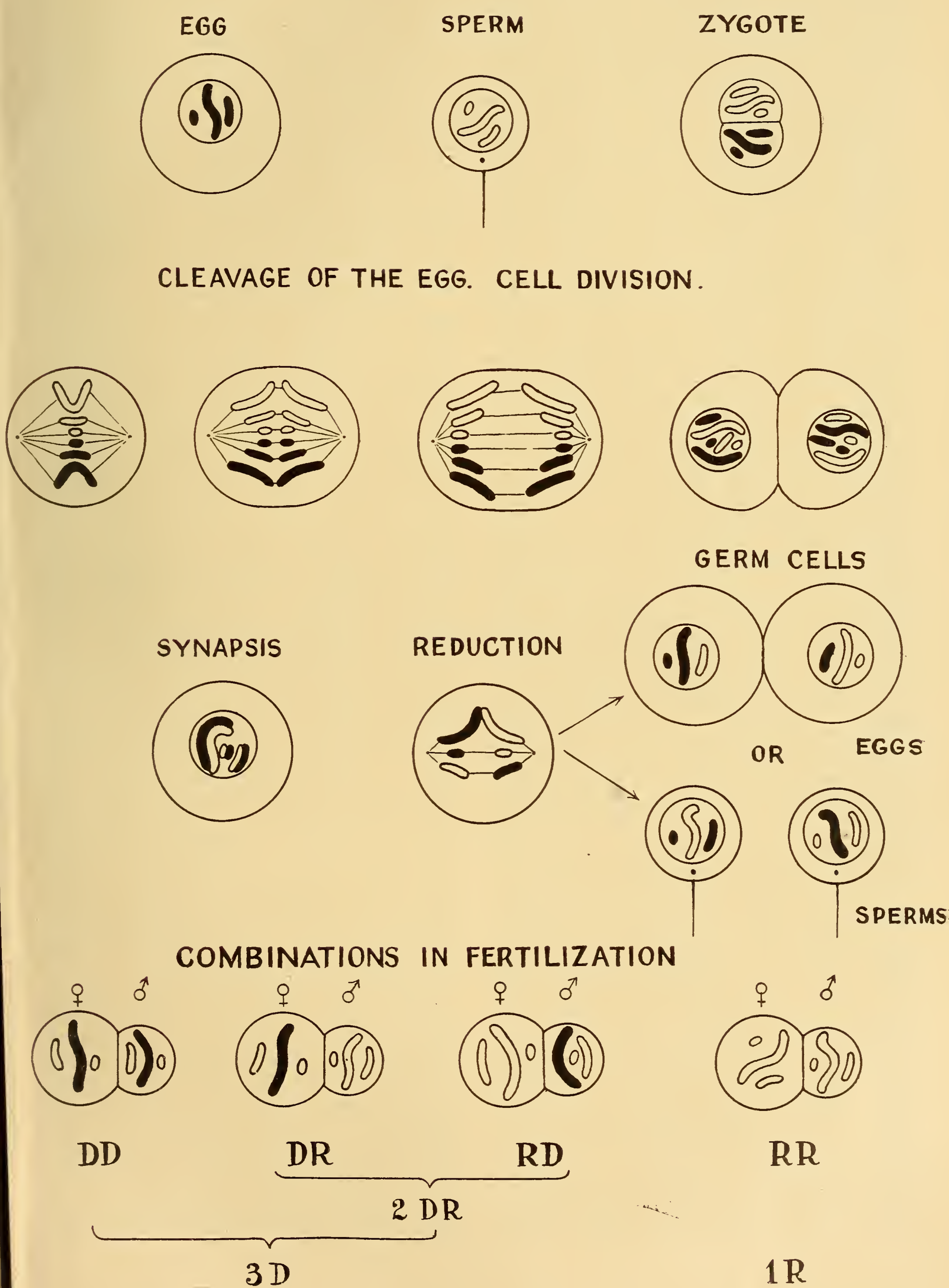
The second fundamental conclusion to which I have referred is that the germ-cells, whether in the male or the female, are not of duplex, but of single or "simplex" constitution. For example, in the four-o'clock, a pink-flowered hybrid produces germ-cells that are in respect to color, no longer hybrid but pure; that is, each egg or pollen-grain bears the possibility of white or of red only, not of both. It is unnecessary to review here the facts upon which this conclusion is based; but we may accept it as conclusively established by numerous and prolonged experiments on the heredity of many kinds of characters in both plants and animals. There are, it is true, some cases (of which the mulatto is an example) which seem to contradict this law, but the most recent inquiries in this field are making it more and more probable that these exceptions are apparent rather than real.

It is clear from the foregoing that in the formation of the germ-cells there must be a resolution of the duplex hereditary composition into the simplex,—that is, a separation or disjunction of corresponding characters derived from the two respective parents; and this fact, first perceived by Gregor Mendel, is one of the most remarkable thus far determined by the study of heredity. It arouses keen curiosity as to whether we can discover in the germ-cells any physical mechanism by which such an effect can be made intelligible. I will say at once that there is reason to believe that such a mechanism has actually been discovered, though we are still in the dark in regard to many of its features, and we cannot say that it represents the only part of the physical basis of heredity. So much, however, may be said, that the nuclei of the germ-cells and of other kinds of cells contain or give rise to certain material bodies known as *chromosomes* which undergo a distribution that shows a remarkable parallel to that of the hereditary characters as revealed by experiment; and the evidence now renders it impossible to doubt that they form at least an important part of the machinery of determination. I ask your attention for a moment to a few elementary biological facts which will enable us better to appreciate the grounds for this conclusion.

The living body is built up entirely out of cells or the products of cells; and the cells arise only by the division of preëxisting ones. All of the cells of the body may thus be traced backward to the fertilized egg or "zygote" as their original ancestor; and the zygote itself arises by the union of two germ cells or "gametes," one of which (the sperm-cell) is derived from the father and the other (the egg-cell) from the mother. The zygote, like all other cells, consists of a mass of protoplasm containing a nucleus. It is entirely probable that both these structures are concerned in determination and therefore in heredity, but I desire to focus attention upon the nucleus, from which the chromosomes arise, and these bodies form the most available point of attack for our microscopical analysis of heredity.

The chromosomes are minute bodies—rod-shaped, loop-shaped, or spheroidal—that appear in the nucleus at the time of cell-division. In each species of plant or animal they are constant in number, and during each cell-division each chromosome divides into exactly similar halves which separate and pass to opposite poles to form the nuclei of the two resulting daughter-cells. The original group of chromosomes thus gives rise to two precisely similar daughter-groups from which are built up the respective nuclei of the daughter-cells. This process begins at the first division of the zygote and is repeated in each succeeding division, the chromosomes reappearing at each division in the same number as before. In many species the chromosomes are of different sizes in the same nucleus; and the size-relations of the chromosomes, like their number, are constant. In species where these relations are clearly marked, we may often see that the chromosomes may be paired off, two by two, according to their size, though we cannot always see this clearly because the size-differences are often too slight to admit of certain recognition.

GENERAL CYCLE OF THE CHROMOSOMES



Nevertheless, observation and experiment abundantly justify the conclusion that the chromosomes of the body-cells are always present in duplicate—in other words, that the chromosome-groups of the adult body are always double or duplex.

We here catch our first glimpse of the parallelism between the chromosomes and the distribution of the hereditary characters to which reference has been made; and this becomes still more obvious when we ask what is the meaning of the duality of the chromosome-groups. This question was first answered by the eminent Belgian cytologist, Edouard Van Beneden, who proved that in the fertilization of the egg two similar single or simplex groups of chromosomes are brought together, of which one is derived from the nucleus of the original egg-cell and the other from that of the sperm-cell. This fact has since been proven to be of general and probably of universal validity and may be spoken of as "Van Beneden's law." It is because all the nuclei of the body are descended from the original double nucleus of the fertilized egg that they all exhibit the double or duplex character that has been described. In respect to the chromosomes, the original germ-cells are of single or simplex constitution, precisely as is the case with their hereditary composition as revealed by experiment. The essential facts will be rendered clearer by the accompanying diagram. Had we no other proof that the chromosomes play some part in heredity, this remarkable parallelism would in itself justify the working hypothesis that such is their significance.

It may seem an incredible conclusion that half of the chromosomes of every cell-nucleus in the body are of maternal descent and half of paternal, as the foregoing conclusions plainly imply. That such is literally the case is, however, practically demonstrated by the remarkable results of Moenkhaus, and others, upon certain hybrids. Moenkhaus crossed two fishes, Fundulus and Menidia, which agree in respect to the number of the chromosomes but differ markedly in respect to their size. The hybrids showed at every stage of development the two kinds of chromosomes side by side in the same cells, and at least approximately equal in number. In these hybrids, accordingly, it is certain that the duplex chromosome-groups of the body cells consist of two simplex groups, one of maternal ancestry, and the other of paternal. It is now hardly possible to doubt that this is true of organisms generally, whether pure bred or hybrid; and this fundamental fact places in our hands a powerful instrument for the analysis of the mechanism of hereditary transmission. I now ask attention for a moment to certain direct evidence that the chromosomes are, in fact, concerned with determination.

First, it has long been known that a cell deprived of its nucleus is incapable of growth or division.

Second, it has been proved by Boveri, in a series of remarkably ingenious and accurate experiments, that disturbances of the normal chromosome-groups in the egg are followed by corresponding disturbances in the type of development. These disturbances were produced by causing the egg to be fertilized abnormally by two sperm-cells instead of one. The details cannot here be given, but the result of such abnormal fertilization is to disturb the normal distribution of the chromosomes to the daughter-cells at the first cleavage of the egg. Though such eggs develop into swimming larvæ, they are almost invariably defective, deformed or even monstrous. Boveri's analysis proves that this is not due to any disturbance in the protoplasm of the egg but results from the false combinations of chromosomes that are established at its first division.

Third, interesting experiments have recently been performed on sea-urchin eggs by Baltzer and by Herbst, which give still more specific evidence in relation to this question. These experiments dealt with what are known as "reciprocal crosses." In most crosses between different species or races, it is immaterial which of the two be taken as the male or the female; the result is the same in both cases. In some cases, however, the

results of such reciprocal crosses are not identical, of which a familiar and long-standing example is given by the cross between the horse and the ass. The cross between the male ass and the female horse produces the hybrid familiar to us as the common mule. If the reverse cross be made, between the male horse and the female ass, the hybrid is known as a "hinny," which is still a mule but one that differs perceptibly from the mule produced by the usual method. In other words the character of the hybrid here depends in some measure upon which parent is taken as the female or the male. The explanation of this particular case is still wholly unknown. The experiments of Baltzer and of Herbst upon analogous reciprocal crosses in sea-urchins prove almost beyond a doubt that in these cases the difference in result is owing to a difference in the mode of distribution of the chromosomes in the early stages of development. The best of these cases is the reciprocal cross between two genera of sea-urchins known as Sphærechinus and Strongylocentrotus, which for the sake of brevity I will designate simply as A and B respectively. A cross between female A and male B is an obvious hybrid, AB, which shows a blending of the characters of the two parents. The opposite cross, between female B and male A, produces a hybrid which shows only the characters of B, that is, those of the female parent alone. Now, microscopical investigation reveals a remarkable difference between these two crosses in respect to the chromosomes. In the first cross the chromosomes of both species are uniformly distributed to the daughter-cells; hence, both parents influence the result. In the reverse cross nearly all the A chromosomes (derived from the sperm-cell) are cast out and degenerate without entering the daughter-cells. The cells of the resulting larvæ thus contain almost exclusively chromosomes of the B parent and hence fail to show the characters of A. It is a very remarkable fact that the number of A chromosomes thus cast out is nearly or quite constant, namely fifteen, while only three undergo the normal distribution. It will naturally be asked why the larvæ do not show some traces of the A character owing to the presence of these few chromosomes. The answer probably is that these particular chromosomes are concerned with characters that are common to the two species and hence afford no visible differential between them.

Not less striking are the experiments of Herbst on this same cross. By means of methods devised by Professor Loeb the eggs of the A species were first chemically stimulated to development for a short time and then fertilized with sperm of the B species. The resulting larvæ showed a remarkable mosaic-like mingling of the characters of A and B, on the whole inclining more to the A type than to the B. Of especial interest were larvæ that showed upon one side of the body characters of both A and B and on the other side only A characters—in other words, these larvæ were of purely maternal appearance on one side while hybrid on the other. Herbst's microscopical studies indicate that these phenomena find their explanation in the fact that the initial chemical stimulation of the egg gives its chromosomes a certain start in development so that the sperm-chromosomes, introduced later, are left in some degree lagging behind and often fail of their normal distribution. Most interesting is the not infrequent case in which the A chromosomes divide normally but all of the B chromosomes (from the sperm) pass to one pole and hence enter but one of the two cells of the embryo. Of these two cells, accordingly, one contains only maternal chromosomes, the other maternal and paternal in equal numbers. It is almost certain that from such eggs arise the observed cases of larvae that are maternal upon one side and hybrid upon the other.

It would be interesting, did time permit, to consider other specific evidence of the determinative activity of the chromosomes in development, but these must suffice for our purpose. We must also pass over the interesting question as to how the chromosomes affect development, an answer to which must perhaps be sought by the biochemist. In the time that remains I will ask attention very

briefly to two specific problems of heredity that appear in an interesting light from the standpoint afforded by the chromosome theory.

One of these, which I will touch upon, is Mendel's law of heredity, to which allusion has already been made. There is no portion of the history of chromosomes more interesting or more diffcult than that which relates to the reduction of the duplex chromosome groups to simplex ones in the formation of the germ-cells; though of the fact of such reduction there is not the least doubt. What seems to happen is that at a particular period, shortly before the formation of the germ-cells, the two chromosomes of each pair unite to form double chromosomes known as "bivalents," and these then divide in such a way that one of its members passes to one pole, the other to the opposite pole. The ultimate result of this is that out of every pair of chromosomes in the duplex groups one member enters half the germ-cells, the other member the other half. It thus comes to pass that each mature germ-cell receives only one member of each of the original pairs, and hence contains a simplex instead of a duplex group of chromosomes. This runs exactly parallel to what has been determined in regard to the disjunction of hereditary characters in hybrids and it is probable that when these phenomena have been fully analyzed they will give us at least a partial explanation of Mendel's law.

Secondly, we may glance briefly at the long-standing puzzle of the heredity of sex, which has been shown within the past few years to be definitely connected with the chromosomes. It was formerly supposed that sex may be determined by external influences, such as nutrition, temperature and the like; but this view has now been nearly, if not quite, overturned. Experiment has definitely established the fact that sex is inherited, like other characters, and that the mechanism of its transmission is similar to that which we see in the operation of Mendel's law. I will illustrate this by an example. As already stated, when a gray mouse is crossed with a white the offspring are gray. If now these gray hybrids be crossed back with a pure white mouse the offspring are gray and white in equal numbers. The reason for this is as follows: The pure white mouse produces germ-cells of but one kind, all bearing the white character. The gray hybrid, on the other hand, produces germ-cells of two kinds, half bearing gray and half white. In random fertilization, accordingly, the chances of white meeting white or gray are equal and hence half the offspring should be pure white and half gray hybrids. It has now become clear that the heredity of sex is of the same general type as such a cross between a hybrid and a pure form; and this explains why in general the two sexes appear in equal numbers. Experiment has clearly proved that sex is determined or produced by a factor that we may call "X" in respect to which one sex is pure bred while the other is of the nature of a hybrid. It is remarkable that in some cases it is the female that represents the hybrid sex, in others the male, but the result is the same in either case. This result, I repeat, was determined primarily by experiments on the heredity of sex; but the point of interest for our present purpose is that exactly the same result has been reached through microscopical study of the germ-cells and in particular of the chromosomes. Such study has proved for a considerable number of animals (1) that in one sex or the other two kinds of germ-cells are formed in equal numbers while in the opposite sex they are all alike; (2) that these two kinds of germ-cells upon uniting with those of the other sex produce respectively males and females; (3) that the male-producing and female-producing germ cells differ in respect to a particular one of the chromosomes which can often be identified by the eye. As an example of this I will cite certain insects (such as the flies or beetles) in which half the germ-cells receive a particular chromosome which is absent in the other half. Corresponding with this, we find that but one such chromosome is present in the duplex groups of male animals while two of them are present in the corresponding groups of the female. Without entering

upon the full details of the analysis it may be stated that these facts must mean that those sperm-cells which contain the extra chromosome are female-producing, the others, male-producing. It thus becomes possible in such cases to distinguish the sex of the animal by mere inspection of the chromosome-groups with the microscope—certainly a remarkable result of cytological investigation. Some of the recent studies in this field make it nearly certain that a similar mode of sex-production occurs in man.

I will give, lastly, an illustration of the manner in which the history of the chromosomes helps us to unravel some of the complicated special riddles of heredity, selecting as an example the heredity of color-blindness in man—an example of the so-called "sex limited heredity." Color-blindness is strictly hereditary and in a very remarkable fashion. In the female it appears only if inherited from both parents, but in the male if inherited from only one parent; for this reason it is far more frequent in men than in women. It is never transmitted from father to son but is transmitted through the daughters to some of the grandsons, though these daughters are not themselves color-blind. A son of a color-blind father, therefore, and all of his descendants, will be wholly free from the defect, but he may expect that some of the sons of his sisters will be color-blind. Surely nothing could appear more capricious and mysterious than such a form of heredity. It becomes however, quite simple and intelligible if color-blindness be in some way connected with or caused by the peculiar chromosome of which I have spoken as characterizing the female-producing sperm-cells. Space would hardly suffice to trace this explanation in detail. It is enough to say that the history of this particular chromosome followed from one generation to another runs exactly parallel to that of color-blindness, and the natural explanation of this parallelism is given by the assumption that the latter phenomenon is caused by the former.

In the foregoing address I have made not the least attempt to give an exhaustive analysis of this complicated subject. My object will have been attained if I have succeeded in indicating to you in what manner the problem of heredity is being attacked from the side of microscopical investigation. In this field of inquiry only a beginning has as yet been made, but enough has been accomplished to give us good hope of continued progress in the future. The principal interest of these cytological investigations seems to me to lie in the fact that they enable us to form a clear mental picture of how the course of heredity may be determined. It is surely a great advance in the study of this complicated problem if the fundamental operations of heredity can be connected with the distribution of visible and definite structural elements in the germ-cells. These elements are not vague formulas or intangible potentialities of development but real things. Behind them, it is true, lies an immense unknown region that will not be fully explored in our generation or in many yet to come, but we are now prepared to proceed with its exploration with confidence that the mystery in which the subject of heredity was so long enveloped will in large measure be dispelled.

STANDARD TIME BY WIRELESS

Under the direction of the Academy of Science, Paris, standard time will be announced by wireless telegraphy daily from the Eiffel Tower for the benefit of ships at sea. The summit of the Eiffel Tower is 984 feet in the air and the range of communication is said to be about 5,000 miles.

This new departure will be of great importance to navigators as it will give them the exact chronometric time, thus enabling them to get at their exact longitude and latitude. The importance of this will be better understood when we say that each chronometric error of a second of time corresponds with an error of over two and a half miles in the exact position of the ship. The signals will be given at eleven o'clock twice a day.

UNWITTING CARRIERS OF DISEASE

IN THE CITY OF BOSTON IN 1909 THERE WERE PROBABLY OVER ONE THOUSAND PRACTICALLY NORMAL PERSONS UNCONSCIOUSLY SPREADING DISEASE

BY SELSKAR M. GUNN

It is now well recognized that man is the most common carrier of disease-producing germs and that inanimate objects which have been suspected in the past as being among the important vehicles of infection are comparatively harmless. Readers of Science Conspectus for February may recall a review dealing with this question in which it was shown that the disinfection of rooms and their contents was being assailed in some quarters and apparently with good reason. It is now well established that people who have had certain infectious diseases are capable of spreading the disease in many instances for a long time after they have become completely convalescent. Similarly it has also been proved within recent years that some individuals who have never suffered from the symptons of certain infectious diseases may yet be acting as hosts for the germs and disseminate the disease to other persons. These two classes are known technically as germ "*carriers*."

Carriers have been demonstrated in typhoid fever, cholera, dysentery, diphtheria, cerebro-spinal meningitis, malaria, sleeping sickness, pneumonia, influenza and various other diseases. It is, of course, impossible to prove by laboratory methods the existence of carriers in those diseases in which the germ has not yet been discovered, but nevertheless we can obtain from other sources, information that proves that some of these diseases should also be included in the carrier class. Scarlet and yellow fevers might be mentioned in this respect. The evidence that there are many carriers of measles or smallpox is slight. The realization of the occurrence of carriers has led to much investigation by sanitary authorities within the last few years and the conclusion has been reached that unless a scheme for prevention of disease takes due cognizance of such carrier cases, it will be unable to make the proper headway in the fight against disease and may in fact lead to almost complete failure.

The problem of controlling infectious diseases has further been complicated within recent years by a greater realization of the fact that there are many "missed" cases; that is, cases which because of the lightness of the symptons are never brought to the attention of a physician or the sanitary authorities and consequently are never placed under any restraint. These cases although in themselves very mild can unfortunately give rise to cases of great severity.

The problem of attempting to control carriers is being considered very largely at the present moment and the recent report of a special committee on typhoid fever of the Massachusetts Association of Boards of Health emphasizes the dangers of carriers, and also the possible methods of controlling them.

Robert Koch, the eminent bateriologist, in 1902 pointed out very clearly the necessity of rendering typhoid fever patients innocuous by efficient disinfection of the body discharges both during the disease and convalescence, and also emphasized a careful inquiry into and supervision of the ambulant and atypical cases met with so frequently. As a result of his recommendation bacteriological stations were established in those parts of Germany which were particularly ridden with typhoid fever and in 1907 there were eleven such stations with a staff of thirty-five bacteriologists attached to them. It

was largely as a result of this progressive step on the part of the German bacteriologists that the typhoid carrier came to be well recognized and thoroughly studied. Space will not permit a detailed discussion of the whole question of carriers for all the diseases previously mentioned, so this article will limit itself primarily to a discussion of the typhoid fever bacillus carrier. The statistics on the subject are at present rather limited and are drawn from different places, so that allowance must be made for the varying circumstances of different populations, but such as they are they show that under ordinary conditions we may expect to find from three to four persons per thousand of the population acting as hosts for the typhoid fever bacilli. Some observers consider that this is a conservative estimate, while others would have us believe that the figures are too high; but even using the lowest estimate (two carriers per thousand population) as a basis, this will mean that in the city of Boston in 1909, according to the population given by the Bureau of the Census for that year, there were about 1,120 individuals who might serve as foci of infection. This explains the well-recognized fact that, even after the purification of the water supply and after excluding all possible cases of typhoid fever that may have come from milk, oysters, other food stuffs, or other sources, there exists a not inconsiderable amount of residual typhoid fever. It is of interest to note that in some cases the typhoid germs have continued to exist in the body of a carrier for many years. One case is reported in which fifty-two years after an attack of typhoid fever the organism of the disease was isolated from the carrier. As a rule, however, the typhoid organisms disappear within a few months and the chronic carrier case is comparatively rare. The case of Typhoid Mary will doubtless be remembered by many. This woman, who served as a cook, within seven years infected twenty-six people in seven different families before she was ultimately apprehended by the health department and forcibly removed to a detention hospital.

The sanitary authorities in various parts of the world have had considerable difficulty in dealing with carrier cases. There is not the necessary legislation to control the carrier and also sanitarians have been hindered by the actual lack of knowledge concerning such carriers. Not only may the carrier infect another person directly by contact but he may infect a large number of people indirectly through milk or from other food stuffs. That is to say, the carrier looking after milking or handling milk in some other way can readily infect this food. There are outbreaks of infectious disease recorded that have been ultimately traced to such a source. Typhoid carriers are frequently found in public institutions like asylums and poorhouses, where the opportunities for contact are considerable and where the people, particularly if mentally unsound, may be very unhygienic in their habits. In the army, also, typhoid fever has been a common disease.

The germ of typhoid fever in the carrier case is located usually in the small intestine, gall bladder or in the urinary system. When the organisms are present in the gall bladder they not infrequently give rise to the formation of gall stones, the organisms of the disease apparently acting as a nucleus for the deposition of the bile salts, and as a result gall stones are found.

The treatment of carriers to rid them of the invading organisms has not yet been placed on a satisfactory basis. The treatment necessarily differs according to the part of the body in which organisms are present. This has to be determined bacteriologically. The drug treatment of intestinal and gall bladder carriers has been entirely ineffective in ridding these persons of typhoid bacilli, although a large number of drugs have been tested. It was hoped that by feeding milk seeded with lactic acid bacilli a permanent cure might be brought about, it being contended that these lactic acid organisms would destroy the typhoid fever bacilli. While this treatment has at times apparently caused the

disappearance of the organism from the discharges of the intestines, yet continued experimentation has shown that this disappearance was not a real one and that the organisms returned later in great numbers. Operations have been performed on infected individuals and the gall bladder either drained and disinfected or removed entirely. It has in some instances been effective in eliminating the organisms from the body. Such treatment is rather strenuous and one can well imagine would not be particularly popular unless the carrier was afflicted with the pains produced by gall stones. The X-ray has also been used but with negative results and vaccines made from typhoid bacilli have likewise proved of no value up to the present time. In the case of carriers where the focus of infection is in the urinary bladder, treatment has been on the whole more successful. This class of carrier forms, however, only a small percentage of the total. The drug urotropine has proved of value in the hands of some observers in eliminating the typhoid fever bacilli but it has not been absolutely successful. It is hoped that a drug called borovertine, which has recently been used with success in a few instances, may prove to be specific in eliminating the organisms.

In other diseases like diphtheria, influenza, pneumonia and probably scarlet fever the germ of the disease is located in the mouth or throat, and it is easy to see how the disease may be spread by carriers of the germs of these ailments.

The result of the discovery of carriers, if properly applied, gives to the health authorities additional means to control those contagious diseases of which the organism has been discovered and is readily recognizable. In outbreaks of diphtheria in schools, for example, where the source of infection is unknown or obscure it is possible to take cultures from children apparently perfectly well and find out in this way which individuals are harboring the germs of diphtheria. They should, of course be treated similarly to those who are sick with the disease, that is to say, isolated and properly quarantined until they are free from the diphtheria germs. This sounds relatively easy but in practice is very difficult, as parents fail to recognize that their child may be a source of danger to others and they resent the quarantine under such circumstances. The discovery of, and the comparative frequency of carriers, emphasizes especially the need for personal hygiene. Infection indicates that the discharges either from the intestines or the mouth of another individual have been able to reach the mouth of a second individual. Strict attention to personal hygiene would largely prevent this, but until personal hygiene is understood from its bacteriological point of view it will be difficult to curtail the number of cases of infectious disease due to carriers.

CONGRESS OF TECHNOLOGY

The most important event in the recent history of the Massachusetts Institute of Technology will be the Congress of Technology which will be held April 10 and 11 to commemorate the fiftieth anniversary of the granting of the charter to the Institute. The Society of Arts was co-existent with the School of Industrial Science, and as a matter of fact, the first public meeting of the Massachusetts Institute of Technology was a meeting of the Society of Arts, which was held December 17, 1862. An account of the proceedings of this meeting was published in the *Boston Transcript* on March 4, 1863.

NOVEL USE OF THE X-RAYS

A would-be immigrant to the United States from China was recently subjected to an X-ray test at Boston to determine his age. Photographs were taken of the wrist and knee bones by the radiographic method at the suggestion of the alien's counsel, who sought thereby to prove his client to be seventeen and not twenty-five years of age, as claimed by the immigration officials. It is reported that the Chinaman did not successfully meet the demonstration.

THE ULTIMATE STRUCTURE OF THINGS

A BRIEF EXPOSITION OF MODERN IDEAS CONCERNING THE CONSTITUTION OF MATTER, IN THE LIGHT OF RECENT DISCOVERY

BY D. F. COMSTOCK

III

Résumé

The statements made in the first article may be summarized briefly thus: All bodies are made up of ultimate particles known as atoms. These atoms exist in nearly one hundred separate species; they are ultra-microscopic in size and show a very definite tendency to form groups known as molecules. The changes called chemical correspond to the rearrangement of the atoms to form new molecules. There is a ceaseless motion of the atoms of all bodies and this is what we call heat. When the violence of the vibration gets too great (*i. e.*, when the temperature gets above a certain point), a solid substance becomes liquid and if the violence still increases the liquid becomes gas.

In the second article the nature and habits of the other fundamental entity, namely the *electron* were discussed. Electrons are minute particles, much smaller than atoms. They are strongly charged with negative electricity and unlike atoms they appear to be all alike. Every atom has when uncharged a certain number of electrons within it. When it has more than this number it is negatively charged and when it has less than this number it is positively charged.

An electron *repels* another electron, or any negatively charged atom, and *attracts* all atoms, but particularly those which are positively charged. In certain ways it is possible to cause a stream of electrons to flow through the heart of a metal. When they do this they appear to constitute the electric current. The actual speed of electricity may be only a few inches per minute, but the speed with which this motion is communicated, the so-called "speed of electricity," is enormous.

Atoms and Life

At this stage it may be well to point out the bearing of atomic ideas on the physical structure of living things. Biologists tell us that all living things are composed of cells, minute objects which are visible in the microscope and have a very definite structure. In general their shape is not very distant from that of a sphere or cube and the so-called "cell wall," like the skin of an orange, simply surrounds the whole. These cells, they say, are singularly independent, sometimes even capable of living alone, in which case the single cell is called a "one-celled animal" (or plant).

From a modern point of view the cell is thus the "vital unit" of all living things. It performs for itself all the life functions which the vast aggregates of cells which we know as animals also do.

Now it is clear that if we are to consider *all* matter to have atomic structure, living substance as well as "dead," then the atom must be very small indeed compared with the cell, for otherwise there would be too few possibilities of structure to account for the wonderful complexity of cell action. You cannot make a rich mosaic with only a few pieces. Now as a matter of fact the complexity of cell action and that of living things in general does not in any way contradict the ideas of atomic structure before outlined, because most cells are so large as to be not only clearly

seen in a microscope but actually to exhibit the detail of their structure. Thus the smallest cell so far studied certainly contains several million atoms at least, and thus the "mosaic possibilities" so to speak, are almost unlimited.

From a fundamental point of view we must look upon the physical side of the changes known as life processes as consisting in the continual rearrangement, grouping and regrouping, of the molecules themselves or of the atoms making up the molecules. With so many atoms composing the physical substance of a single cell the possibilities of change are vast.

Although living things, as we know them, in no case seem to contradict atomic concepts, yet it is well to notice that living things *many* thousand times smaller than the smallest we know would contradict them, for such imaginary living things could contain too few molecules to undergo the complex changes which are inseparable from life.*

Molecules and Chemical Action

As has been said before, it seems more than probable that the forces involved in chemical affinity are electrical in character. That is, the atoms which form the groups known as molecules are held together by electric attraction. Thus a molecule of hydrochloric acid is composed of one atom of hydrogen and one atom of chlorine, and the two cling together probably because the chlorine atom has a negative charge while the hydrogen atom has a positive one and "unlike charges always attract each other."

When hydrogen gas and chlorine gas are put together in a vessel, heat or even light will cause them to combine suddenly and form hydrochloric acid. That is, each atom of one kind becomes attached to one of the other kind, forming a molecule of the new "compound," hydrochloric acid.

We shall probably not be far wrong if we picture the mechanism of the process of union somewhat as follows: The light or heat detaches from some of the atoms a few electrons and these bound about at random between the molecules of the two separate gases. A very important fact then makes itself felt. As was said in the last article the different kinds of atoms have very different attractions for electrons, and, in the present case, the attraction of the chlorine atoms is vastly the greater than the hydrogen. Thus it will happen before long, since a few new electrons are being detached constantly, that every chlorine atom has one electron *too many* while every hydrogen atom has one electron *too few*. This means, of course, that each of the former attains a negative charge (see last article), and each of the latter a positive one. The remainder of the process consists merely in the attraction and permanent combination in twos of these atoms of unlike charge to form the groups which we call hydrochloric acid molecules.

It is to be noticed that some kind of disturbance, in the above case heat or light, is necessary to keep up the supply of "free electrons." We therefore see that were there no heat or light, or were the intensity of these below a certain limit depending on the nature of the substances, we could get no chemical action. This inertness would be a property of *all* substances in the dark at the so-called "absolute zero" of temperature, which, it will be remembered, is 273 degrees centigrade below the freezing point of water.

Atoms, Electrons and Light

There are the best of reasons for believing that light waves are electric in character. There seems to be no difference at all between light waves and the electric waves used in wireless

*Note.—In apparent contradiction to the modern conception of matter are the ideas of the so-called "high potentists" in medicine, As is well known they believe in the beneficial effects of *very* dilute solutions of the substance they are using, so extremely dilute in fact that it takes but a simple calculation to show that in some cases they can have but one molecule to a thousand gallons of their solution; so that a half pint of such a solution has only one chance in thirty of containing that single molecule. The idea does not appear, therefore, to be in harmony with the prevailing conceptions of the structure of matter which are here set forth.

telegraphy except that the latter are very much "longer" and the vibration is very much slower than in the former case. Light waves and "wireless" waves are thus related in the same way that a high pitched sound is related to one of low pitch. Now "wireless" waves (*i. e.*, Hertz waves) are always produced by causing a charge of electricity to oscillate to and fro. Waves are thus set up in the "ether of space" in a manner somewhat similar to the way sound waves are set up by a vibrating bell. Since an oscillating charge is thus the cause of these waves it seems but reasonable to ask what electric charge is responsible for the closely similar but enormously more rapid waves of light. Now as a matter of fact this question has been answered fairly definitely, for by studying the effect of a powerful magnet on various sources of light it is possible to get information on the nature of the vibrating charges within the glowing body which must be held responsible for the light waves emitted. It has been found by a distinguished Dutch scientist that *the charge is that of the electron.* Here again, therefore, we find ourselves thrown back on the same fundamental entity.

The electrons are to be considered as in more or less violent oscillation to and fro, *probably* within, though *possibly* without, the atoms of a glowing body.

The "radiant heat" from the sun is also of this electric wave type of vibration so that the sun is a light and heat radiator because of the vast number of vibrating electrons which it contains.

Evidence of Orderly Structure.—Although much of the light and heat given out by bodies seems to be due to the *random* vibration of the electrons within them, this is by no means the case in general. Almost all gases when caused to give out light, emit it in the form of "pure notes" that is, in the form of waves of definite frequency. The light which we get from a white hot nail consists of all possible frequencies of vibration. It is similar to what we would get in sound if we took a long rod of wood and struck *all* the keys of a piano at once. The light however which we get from a glowing *gas*, such light as comes from the long glass tubes used frequently now in garages and known as Cooper Hewitt Lamps, is not of this chaotic composition. It can be shown to consist of "a few pure notes" to use the same acoustical analogy. These pure "notes" or colors are superimposed upon each other and hence the combination is a close analogy to what we call in acoustics a musical chord.

The definite "light notes" emitted by one substance when in the gaseous form are perfectly characteristic of that particular species of atom and *no other kind of atom gives off the same notes;* no other kind of atom, that is, emits light of just the same frequencies.

Apparently this can only mean that the electrons within one kind of atom are in some perfectly definite arrangement, an arrangement which remains the same and which differs markedly from that to be found in atoms of other species.

Very little is now known as to the structure of the atom but the question of its structure is the central fundamental problem in modern physics and the discovery of radium and similar substances has thrown great light upon the problem already.

HEAT CONDUCTIVITY OF CONCRETE

Charles L. Norton, professor of heat measurements at the Institute of Technology read a paper recently before the National Association of Cement Users giving some of the thermal properties of concrete.

It is interesting to note the great difference between the tamped and the untamped concretes made from stone. The one was as porous as possible and the other as dense. One transmits nearly twice as much heat as the other. The cinder concrete, as is commonly believed, is much better, being nearly three times as effective as the denser stone concrete in retarding the flow of heat.

COLLOIDS AND COLLOIDAL SOLUTIONS

AN INTERESTING GROUP OF SUBSTANCES, THE STUDY OF WHICH HAS OPENED UP A NEW FIELD IN SCIENCE AND IN THE ARTS

BY ELLWOOD B. SPEAR

II

Summary of the Previous Article

Very small particles suspended in a liquid form a colloidal solution. If the tiny pieces are metal-like bodies the solution is called a colloidal suspension; if the particles are jelly-like the solution is called a true or emulsion colloid. The particles vary in size from molecular dimensions to those large enough to be seen by an ordinary microscope. Blood, milk and muddy water are good examples of colloidal solutions. The particles may be caused to unite or coagulate. The clotting of the blood, the rising of cream and churning of butter are examples of the coagulation of colloids.

Particles Carry Electric Charges.—Very small particles suspended in a liquid become charged positively or negatively, depending upon the nature of the substance of which they are composed, and also upon the character of the solvent. Colloidal suspensions of the metals such as gold in pure water are charged negatively and would, therefore, go to the positive pole if a current were sent through this solution, while gelatine in water is charged positively and would travel toward the negative pole, that is, in the same direction as the copper or silver ion.

In order to better understand the cause of the charge of these particles it will be necessary to digress for a moment and discuss the phenomenon technically known as adsorption.

Adsorption.—A piece of glass dipped in water will be wet if the surface is perfectly clean and scientists say the water that sticks has been *adsorbed* by the glass. The phenomenon where small amounts of one substance are held to the surface of another is called adsorption. We can easily convince ourselves that this property of adsorption is not the same for all substances because on greasing the glass the water no longer sticks to it. In other words, grease will not adsorb water. Sometimes the adsorbed substance actually penetrates to the interior of the adsorbent. This latter process is usually very slow and requires several hours for completion while adsorption on the surface is very rapid; in most cases it is almost instantaneous.

Colloids Have the Property of Adsorbing other Substances.—Many colloids have this property of adsorption to a very marked degree. The tiny particles not only adsorb quantities of gases, liquids and solids on their surfaces, but often large amounts of one another. For instance, gold particles adsorb colloidal gelatine. This will be referred to later. Small particles of carbon in the form of charcoal or lamp black exhibit the property of adsorption very prominently. Advantage is taken of this in the clarifying of sugar. The coloring matter in the syrup is there as colloidal particles and if the liquid is passed through charcoal beds all these colored particles are adsorbed on the surface of the carbon so that the syrup comes out colorless. When this is allowed to solidify and crystallize we obtain white sugar.

Cause of the Electric Charge.—The electric charge on colloids is explained by this property that they have of adsorbing other substances. If the colloid adsorbs more of a positively charged substance (such as a charged hydrogen

atom, called the *hydrogen ion*), than it does of the negatively charged ion the particle itself must necessarily become positively charged also. Gold and platinum colloidal particles adsorb the hydrogen ion and therefore move towards the negative pole in a solution containing free acid, if an electric current is sent through, while the same particles are negatively charged in a solution containing an alkali because the negative part of the latter, called the *hydroxyl ion*, is adsorbed by the metallic particles. Pure water contains some hydrogen and some hydroxyl ion. Colloidal particles of gold in pure water, having a greater liking for hydroxyl than for the hydrogen ion, adsorb more of the former and thus become negatively charged in pure water while particles of gelatine in water, adsorbing more of the hydrogen than of the hydroxyl ion, become positively charged. If, however, we add a large excess of an alkali to an aqueous solution of gelatine the latter will adsorb large quantities of the hydroxyl ion and the particles of gelatine, therefore, become negatively charged.

It will doubtless occur to many readers to ask what is the difference then between the charge on the atom and that on the colloidal particle. The answer is, that there is probably no difference in kind but only in quantity. The very plausible assumption is made that all charged hydrogen atoms carry the same amount of positive electricity irrespective of their surroundings and further that the mass of all hydrogen atoms is the same. Therefore, for the hydrogen ion the ratio of the charge to mass is always the same, or, in other words, is a constant. Colloidal particles of the same substance, on the other hand, are of varying sizes and, therefore, have very different masses. The charges depend upon the environment, sometimes being positive, sometimes negative. The ratio of charge to mass in the case of colloids cannot therefore be a constant.

As has already been said colloids move in the electric current if the latter is sent through the solution,—positive colloids toward the negative pole and negative colloids toward the positive pole, or, if the colloid can be held stationary the water will move in the opposite direction. When the colloid moves in the current the phenomenon is called *cataphoresis*. When the colloid is held stationary the water moves and the phenomenon is called electrical *endosmosis*. Advantage is taken of both these phenomena in the arts. For example, water is often removed from peat by electrical endosmosis.

Stability of Colloids and their Coagulation.—Curiously enough the electrical charge on colloids seems to play a very vital part in their stability. Particles charged with the same kind of electricity would repel each other in solution and would not tend to unite or grow. If now the charges on negative gold particles were neutralized by allowing adsorption of a positive substance it would be easier for these particles to increase in size by the union of two or more to form larger ones. This is indeed the case, for it has been found by experiment that colloidal suspensions fall out most easily when they neither move toward the positive nor the negative poles in the electric current and cannot, therefore, have a charge on them. The neutralization of the charges is achieved by adding a positively charged substance that the colloidal particles will readily adsorb.

From this theory it would follow that if colloidal particles adsorb a substance having the same kind of charges as they themselves possess the stability of the colloid would be increased. This has been found to be the case in very many instances. It must be confessed, however, that very large excesses of all ionized substances will coagulate colloids regardless of the kind of charge on either the colloidal particles or the substance itself. Up to the present no adequate explanation has been offered for this phenomenon. Technical use is very often made of this property; for example, soap is thrown out of the liquid in which it is made by adding common salt. This process is known technically as "salting out."

Protection of one Colloid by

Another.—Before iron can be welded or tin soldered the surfaces to be joined must be clean, that is, free from any foreign material. This is also true of the union of colloidal particles during coagulation. Colloidal particles of gold will adsorb and cover their own surfaces with small amounts of gelatine if these two kinds of colloids are brought together in the same solution, and it is much more difficult to cause gold to coagulate under these circumstances. The gelatine is then said to protect the colloidal gold; that is the colloidal solution is more stable.

Colloidal Particles are in Rapid Motion.—Another striking property of all colloids is the fact that the particles are in rapid vibration. If colloidal gold is viewed under an ultramicroscope the particles seem to dart and shoot hither and thither like a lot of school children at play. In fact, the rate at which the charged particles move can be determined by actual measurement under the ultramicroscope. There is now a law of nature which we know from our every-day experience to be true, that it is much easier to move a small body than a large one, or to stop the motion of a light body than to arrest a heavier one. We should expect, therefore, that the small colloidal particles would move much faster than the larger ones, and this is found to be the case. If now the speed at which the colloidal particle of a known size moves is measured, it should be possible to calculate how fast it would move if it were as small as an ordinary water molecule. This calculation reveals the extraordinary fact that the molecules of matter move with the identical speed that scientists have ascribed to them. (See Science Conspectus, page 51.) This, then, is another excellent collaboration of a fundamental conception of matter, namely, that the molecules and atoms are in a state of constant vibration.

Colloids Catalize.—Many colloids have the interesting property in common with other substances of causing certain chemical reactions to proceed at a much faster rate than otherwise would be the case without suffering any permanent change themselves. For example, colloidal gold will decompose hydrogen peroxide (commonly known as "peroxide") very rapidly. The action is called *catalysis* and is made use of in an enormous number of instances in industrial life. The substance that increases the rate of the reaction is called a catalizer. Very many of the reactions in the human body, especially with regard to the digestion of food are due to catalytic action. Wounds are often cleansed by washing with peroxide of hydrogen, because the pus, which is itself a colloid, catalizes the decomposition of the peroxide into water and oxygen. The oxygen thus set free actually burns up and destroys the germs together with the pus, so that the latter has aided in its own destruction. So-called negative catalizers are also known; that is, substances which by their presence slow up the reaction, and some scientists hope eventually to be able to control high fevers by use of a negative catalizer to slow up the reaction by which the high temperature is caused.

Colloids Can be Poisoned.—The catalytic properties of colloids can be lessened and in some cases completely destroyed by the addition of certain substances which seem to act on the particles like poisons. In fact, it is a striking coincidence that every known poison for the human system will partially, it not completely, destroy the catalytic power of colloidal particles of gold or platinum. Such poisons as carbon monoxide, hydrogen sulphide and hydrogen or potassium cyanides have a very intense effect upon the colloidal solution and extremely small quantities of these poisons will materially impair the usefulness of the colloidal particles as catalizers.

ORGANIC PROCESSES PARALLELED

In a recent issue of *Science* appears a review of "Théorie physico-chimique de la vie et générations spontanées," by Stéphen Leduc, Professor à l'école de

medecine de Nantes. This book takes up the world-old problem of the ultimate nature of living matter in an interesting way, and brings up to date the work that has been done toward establishing a "synthetic" biology. The author starts with the proposition that we know as yet nothing of life itself, having learned only a few facts regarding the phenomena accompanying its manifestation. These phenomena, he points out, have all analogies in inorganic matter, and it is to painstaking study of these analogies that we must look for present progress toward the development of synthetic biology. He takes up the laws of solutions, molecular concentrations, osmotic pressures, cryoscopy, periodicity, thermodynamics, diffusion, and fields of force, all considered as facts entering into organic phenomena.

Some of Leduc's experiments show remarkably close parallels with organic processes. By diffusion, he produces geometrical forms, circulation of "cytoplasm," and pseudosegmentation of "cells," and he describes osmotic "organisms" that bear a curious resemblance to algæ and fungi. They will grow "roots," "stems," and "fruits," he points out, the latter sometimes appearing of different color. These growths have periods of rest and activity, they show cell-like divisions and circulation of the fluid contents; they repair wounds, and respond to external stimuli. Some of them are amœboid and motile, while others form spicules at the surface of the solution.

Leduc makes no claim that these "organisms" bear any resemblance in constitution or properties to living substance, but he does believe that the physical and chemical conditions that produce them are constantly occurring in organisms and contributing to their complex activity, and it is from this angle that he thinks this most fascinating and most difficult of all biological problems must be attacked. M. R. S.

The April number of Science Conspectus will close Volume I.

STAINING OF WOOD IN LIVING TREES

The interesting experiment of dyeing the wood in living trees has been successfully carried out by making a fine groove around the trunk deep enough to expose the wood just inside the bark. A string having a diameter slightly greater than the groove is wound around the trunk completely filling the groove and thus protecting the wood from the action of the air. If now the ends of the string dip into a solution of coloring matter, the latter is absorbed by the tree. The solution is renewed until the wood is dyed to the desired intensity. Observations are made from time to time by boring small holes into the tree. The length of time necessary to dye the wood depends upon the species of tree, the temperature and the season of the year. The best results are obtained just before the leaves fall in the autumn. The absorption of the coloring matter is selective, that is to say, all coloring matter is not absorbed by every tree, and in general a decided preference is shown for the colored extracts of the bark of other trees. The wood is not stained uniformly, and the mottled effects are very beautiful. The color in the heart of the tree is not perceptibly changed.

E. B. S.

SUB-SURFACE CAVITIES

In several cases railroad tunnels have revealed the existence of large caves of which there is no external evidence. These caves or rifts are very large in some cases and seriously interfere with the driving of tunnels. The latest instance of this is in connection with the new railroad line to connect Rome and Naples. A tunnel four and one third miles long under Mt. Orso struck a deep rift 200 feet wide, apparently descending to the sea level. It will be necessary to go around this cavity and work from the other side. The method by which the road will be carried over the cavity has not yet been decided upon.

ALL ABOUT THE RUBBER INDUSTRY

ORIGIN AND METHODS OF MANUFACTURING RUBBER—RUBBER SUBSTITUTES AND SUBSTITUTES FOR RUBBER—SYNTHESIS OF RUBBER A QUESTION OF TIME

BY FRED L. BARDWELL

During the twelve months ending June 30, 1910, there were imported into the United States 101,044,681 pounds of crude rubber, valued at $101,078,825. Assuming that this rubber was all used in the manufacture of rubber shoes, vehicle tires, and the thousand-and-one other articles in which india-rubber is a necessary or desirable component, and further, that on the average, rubber constituted 25 per cent. of the manufactured articles, some idea may be formed of the enormous importance of the rubber industry to this country. Moreover, when one realizes that in Great Britain and the European Continent the industry is proportionately greater than in this country, its tremendous importance to the civilized world becomes very impressive.

As it comes to the market, rubber—or caoutchouc as it is more properly called—varies considerably in its qualities, depending upon the plant from which it is obtained and the manner in which it is prepared for the market. Like a much-advertised proprietary medicine it has certain properties "peculiar to itself," the most important of which are its elasticity and resiliency. Caoutchouc belongs to a class of bodies called colloids: that is, uncrystalized substances which, to a greater or less extent, resemble glue or gelatine in their behavior. In some respects it resembles a very thick or dense liquid rather than a solid.

Although india-rubber has been known for more than four hundred years, it was little more than a curiosity until the beginning of the eighteenth century, when it began to be manufactured into useful articles.

Among the first importations were shoes of rude shape which were made by smearing lasts or forms of clay with the milk-like sap from which caoutchouc is obtained. By drying the sap and applying layer after layer until the desired thickness was attained, a rudely formed foot-covering was made which had at least the merit of being waterproof. Later certain importers in this country sent wooden lasts of better shape to the regions where rubber was collected, and received in return shoes of more correct form and better quality than those of wholly native manufacture.

It soon became apparent to manufacturers that caoutchouc would become more useful if other substances could be incorporated with it in order to enhance its many useful properties and increase its durability. After years of patient experimentation under discouraging circumstances, Charles Goodyear discovered in 1839 that by heating rubber with sulphur a body could be formed which possessed the elasticity and resiliency in a remarkable degree, while the peculiar adhesiveness or "tackiness" (a property of raw rubber which is objectionable in manufactured articles) was absent. At about the same time Hancock in England made practically the same discovery; and Alexander Parkes, also in England, discovered that thin sheets of caoutchouc were changed in a similar way if dipped in a solution of chloride of sulphur. From these two inventions have been developed the two processes known as hot and cold "vulcanization." This term vulcanization was first applied by Goodyear to the process of causing sulphur to combine with caoutchouc under the influence of heat. Later it was extended to any process which resulted in the combination of caoutchouc and sulphur; and today would probably be used to characterize any process resulting in the toughening or hardening of rubber, thus rendering it less susceptible to changes in temperature. Colloquially it is even used by cobblers and tire repairers to refer to

the mending of various articles made of rubber; and, indeed, there is good reason for this in the fact that the mending is accomplished by the chemical union of rubber and sulphur.

In modern factories the articles are formed from the mixture of rubber, sulphur and other ingredients (this mixture is called the "compound"); and the vulcanization is accomplished by placing the articles in closed chambers and subjecting them to heat. The desired character of the article determines whether the process shall be carried out in a dry atmosphere or in an atmosphere of steam. This is called "hot vulcanization."

"Cold vulcanization" is used in some cases where heating would be impracticable. In most cases where it is applied the material is thin, or only surface vulcanization is desired. The process consists in dipping the articles in a solution of chloride of sulphur and the chemical change consists, not only in the union of sulphur, but also of chlorine with caoutchouc.

As the industry has developed and improved methods have been introduced through study and experimentation, the percentage of rubber in manufactured articles has decreased. This does not mean that the quality of the products has also decreased; in fact, in the majority of cases, the incorporation of other substances with caoutchouc has widened its usefulness and improved the quality of the products. Just as the union of small amounts of carbon, nickel, chromium or other elements with iron has produced many forms of steel which can be used where pure iron would not be applicable, or as several metals may be mixed to make useful alloys, so the mixture of whiting and the oxides or sulphides of certain metals, as well as various organic substances with caoutchouc may make a better article for a given purpose than could be made from pure vulcanized rubber. An automobile tire, for instance, made up in all its parts of pure rubber, would be a clumsy and comparatively useless thing, and much more expensive than it is today. Although it is probably safe to say that an ordinary tire of recent make does not contain more than 50 per cent. of rubber, that rubber is so distributed and so variously "compounded" in the different parts of the tire, that the finished product is lighter and far more useful than could possibly be the case if it were made of pure rubber.

An ordinary automobile tire consists of the outer casing, or "shoe" and the inner tube. The latter is the part which is inflated and is made of almost pure rubber. The "shoe" is built up of layer after layer of canvas or duck which has been coated with a thin layer of pure rubber, and on this base are superposed layers of rubber "compounds" of varying composition. When the tire has been made into the proper shape, it is subjected to heat and thus vulcanized. The outer layer, which is to receive the greatest wear is so "compounded" that when it is vulcanized it will be very tough and resistant, although it contains less rubber than do some of the inner layers. In the same manner (although not so elaborately) rubber shoes are made containing from 30 to 50 per cent. of rubber according to quality. The remainder consists of sulphur, whiting, litharge, asphaltum, and other materials which are used, either with the professed intention of improving the product, or for frankly stated purpose of adulteration. It is probable, however, that if the purchaser of a pair of "rubbers" were today given his choice between a pair of shoes of recent make, and a pair of those made of pure rubber fifty years ago (at the same price), he would choose the more recent product in spite of the general complaint that nothing is made as well now as it was in the "good old times."

Just as almost every meritorious article of trade is followed by imitations which are "just as good," so during the last 75 years there have been a very large number of substitutes invented. These may be divided into two classes: rubber substitutes and substitutes for rubber. Under the former head should be placed all those materials in which the attempt has been made to fabricate substances

which would, in part or wholly, replace caoutchouc in rubber "compounds." Almost daily one may read of new inventions of this sort which enjoy the brief notoriety of one notice in the daily press. Almost every known material has been honored by being mentioned as a component of some new substitute for rubber; a morning's unfortunate experience with a poorly cooked cereal or an especially tough omelet being sufficient, in some cases, to lure the luckless victims to visions of untold wealth achieved through the manufacture of rubber shoes or vehicle tires from "cornine" or "albumenine" without the admixture of a grain of rubber. Nothing, however, has yet been made which possesses the four properties of caoutchouc: elasticity, resiliency, chemical stability and vulcanizability (if one may be pardoned for coining such a word).

There are, however, certain products of considerable value as "fillers" or adulterants which have properties making them serviceable in replacing a portion of the rubber used in a compound. These are all made up of "sulphured" or "blown" oils. When certain of the so-called "drying oils," such as linseed or rapeseed oil, are treated with chloride of sulphur, or are heated with sulphur, they form a somewhat elastic wax-like material which can be successfully incorporated into rubber "compounds," and, although in no sense equal to caoutchouc, they serve in its place.

Substitutes for rubber, on the other hand, are products which are used, not as adulterants or fillers in compounds, but as basal materials in the manufacture of articles which might otherwise be made from rubber. Celluloid, for instance, a mixture of nitrocellulose (gun cotton) and camphor, is used in enormous quantities in the manufacture of articles which formerly were made of hard rubber. Velvril, an English product, consisting of a mixture of nitrated oils with nitrocellulose, is a wax-like body possessing little elasticity or resiliency. It is used extensively for insulation purposes and for the manufacture of certain articles in competition with rubber. Bakelite, a more recent invention, is produced by the chemical condensation of phenol carbolic (acid) and kindred bodies with formaldehyde. It can be prepared in a plastic state and moulded into various forms and hardened, or it may be made into a hard material; it can be mixed with pigments and is capable of taking a high polish and is being increasingly used instead of vulcanite or hard rubber. Casein, the substance which forms the curd of sour milk, is employed in many forms to make articles formerly made of rubber. It somewhat resembles ivory in hardness and texture. The latest material to be brought forward is a combination of vegetable and animal albumen, which by proper treatment yields products similar to those made from Bakelite. It is called protal.

Reclaimed Rubber and Shoddy

As a matter of economy the utilization of the enormous quantities of waste rubber which exists in worn-out shoes and vehicle tires, as well as in other refuse, is a prime necessity. Today the gathering of scrap rubber is a business by itself, while the preparation of this scrap for use in the rubber factories is only less extensive than the manufacturing. The old rubber used in factories may be divided into shoddy and reclaimed or "devulcanized." The writer must acknowledge that the distinction between the two terms is somewhat shadowy, as they are used interchangeably in many cases; but, in general, it may be said that shoddy is old rubber which is sent back into the works to become a part of new compounds with no other preparation than fine grinding, while reclaimed or devulcanized rubber is scrap which has been so treated chemically or otherwise as to make it plastic and more like the original caoutchouc.

As the scrap comes to the hands of the reclaimer it is full of all manner of dirt and grit; moreover, scrap from hose, belting, shoes and tires consists largely of cotton (sometimes woolen) fiber used in the construction of the original articles.

The scrap is first sorted into various

grades and subjected to various modes of treatment for the removal of the dirt and fiber. Although the processes vary in detail, they all consist in the grinding of the scrap by means of powerful rollers, separating bits of iron wire and nails by means of a magnet, and the removal of the fiber either by mechanical or chemical means. When mechanical means are employed the scrap is ground to a fine powder and a strong current of air is blown through it, thus carrying away all the lighter fiber, while the heavier rubber remains behind and is ready either to be used as "shoddy" in new mixtures, or to be put through a subsequent process of "devulcanization." The chemical method of fiber removal consists of treating the scrap either with an acid or a caustic alkali which does not materially affect the rubber, while it causes the disintegration of the fiber which can then be removed by washing.

The ideal of the reclaimer has always been to reverse the process of vulcanization and to return the material to the condition in which it was after the mixing of the caoutchouc, sulphur, litharge and other materials. This would mean the breaking down of the chemical compound formed when the vulcanization was accomplished; that is, it would require the separation of the sulphur and the caoutchouc which had combined chemically. This object has not been successfully accomplished as far as is known to the writer, without also breaking down the caoutchouc. The most that has ever been done is to soften the material—to make it more plastic and adhesive.

Two methods have been employed in attempting to remove the sulphur, each of which has been partially successful:—First, treating the finely ground scrap in large receptacles made of boiler iron, with superheated steam. By this means considerable amounts of sulphur combine with the hydrogen of the steam and pass off into the air as sulphureted hydrogen. This removal of a portion of the sulphur and the high temperature at which the operation is carried on serve materially to soften the substance. Second, some processes utilize the chemical fact that alkalis, such as caustic soda, will combine with the sulphur in vulcanized rubber and thus remove it. This is carried out by boiling the scrap in tanks filled with solution of caustic alkali and finally washing it thoroughly with water.

The material thus "devulcanized" is frequently mixed with varying proportions of oils in order more thoroughly to soften the mass. The "milling," that is the mechanical treatment, is a very important factor in the reclaiming process.

By methods similar to those outlined above, the waste rubber of the world is almost completely utilized; and rubber scrap is almost as important a staple of commerce as is raw rubber itself.

Sources of Caoutchouc

Caoutchouc is a constituent of the latex or juice which exists between the layers of the bark of many trees, shrubs or vines which grow in nearly all parts of the tropical and semi-tropical world. In the temperate zones also there are plants whose sap contains caoutchouc, in quantities too small, however, for commercial purposes. Within a short time, it has been seriously proposed to utilize the leaves of the banana plant and even the skin of the fruit, which is said to contain small quantities of rubber in its sap, is being experimented with.

Although there are so many plants from which caoutchouc may be obtained, those most frequently mentioned are the *hevea Braziliensis*, found native in Brazil, Bolivia and Peru; the *castilloa elastica*, found wild in Colombia and Central America. In Africa the *landolphia*, a large vine and the *kickxia Africana* are the principal sources; while in India the Malaysian Peninsula and the East Indies the *ficus elastica* (the "rubber plant" of our greenhouses) has, until recently, been the most important source. At the present time, also, large quantities of good rubber are being obtained from a shrub called *guayule* which grows in Central Mexico and southern Texas.

Until within a few years the collection of caoutchouc has been left almost wholly to the natives of the tropical lands, and the volume and quality of the

supply has been dependent upon men of little skill and less efficiency. In most cases the tapping of the trees has been not only wasteful but destructive. All this waste and inefficiency has added greatly to the cost of collection and has also detracted from the quality of the product.

In recent years the problem of the rubber supply has been approached from a scientific standpoint, and the task of placing caoutchouc upon the market is rapidly being taken up by men of skill and scientific training. In Brazil, for instance, where alarm was felt because of the apparent depletion of the *hevea* (the source of the finest rubber known), improved methods of collection, government supervision, the opening up of new tracts by building railroads and the improvement of water ways—all these things have tended to increase the output of the Amazon country and to make it more uniform in quality. What has been shown regarding the improvement in Brazil is typical of what has been going on in other fields so that there is great improvement both in quantity and quality in all parts of the world. Moreover, successful attempts have been made to cultivate certain species of trees. This is notably true in case of the *hevea* and the *castilloa*. In case of the *hevea* the success has been so remarkable that there are hundreds of thousands of trees in Ceylon and the Malaysian Peninsula as well as in other parts of the far East, which are now yielding such large quantities of rubber of superior grade that the market is being influenced by it to a considerable extent. Besides this there are millions of young trees planted in India, the East Indies and in Africa, which will be of bearing age in a few years.

In Central and South America, also, the cultivation of the *castilloa elastica* is being carried on. This will, in time, cause a large increase in the supply of those grades of rubber which are called "centrals."

Not only does the cultivation of the trees increase the amount of rubber, but the fact that, under plantation conditions, scientific treatment of the latex is possible, has already brought about great improvement both as to the quality and uniformity of the rubber placed upon the market. It may be expected that improvement along these lines will continue, and that the same general methods will be followed in the native forests all over the world.

Much has been said within a year about the supply of rubber not keeping up with the demand; and the hysterical flurry of a few months ago was the result of a feeling (arising, however, from lack of information) that a rubber famine was imminent, but the prophesies of men with cooler heads have come true, and today the talk of famine is not heard.

Can Caoutchouc be Synthesized?

For years the synthetical preparation of india-rubber has been the opportunity of the charlatan, the dream of inventors and the aim of the chemist. From the chemist's standpoint this synthesis has been one of the most baffling of all the problems of organic chemistry, and a prominent writer on subjects dealing with the rubber industry has recently said that the commercial synthesis is not probable. The methods of the scientist, however, are as persistent, as patient and as relentless as the practiced hunter stalking his quarry, and chemists will not rest until the thing is accomplished. Even now it is believed that the chemical constitution of the substance has been determined by Professor Harries of Kiel; and it has actually been synthesized on a laboratory scale. What remains to be done (and the saying is much easier than the accomplishment) is to find a method and raw materials cheap enough so that the finished product can compete with the natural product. When (as is the case) it is reported that Ceylon *hevea* rubber can now be laid down in London for a shilling a pound, one can appreciate the magnitude of the chemist's problem. It is even now rumored that the largest chemical company in the world is building works for the manufacture of synthetic rubber. Whether this rumor is true or not at present, its accomplishment is only a question of time.

A DELICATE BLOOD TEST

The serological test is the latest development of science on the subject of discriminating between different kinds of blood stains. It is so marvelously delicate that the flesh of an Egyptian mummy responds readily to it. Dr. Rackman of the Royal Society of Public Health in London recently gave a wonderful demonstration of this test. The previous methods of discriminating between different kinds of blood were based on the appearance of the blood corpuscles under the microscope. The new test is based on the chemical character of the albumen dissolved in the blood serum.

Several test tubes had been provided which contained what is known as antiserum which had been prepared by injecting the blood of some animal into a rabbit. The different kinds of blood in different sets of rabbits which had been treated were those of a man, a horse, a pig and an ox.

After a certain number of injections the rabbit's blood was found to contain a substance known as precipitin. A drop of blood from a rabbit, containing the precipitin caused by human blood has a curious effect on the albumen dissolved out of human blood by a salt solution. A few drops of this solution was placed in a very small test tube and a drop of the antiserum was allowed to fall upon it. As the drop settled to the bottom of the tube a ring of filmy opalescence formed at the point of contact between the two liquids. When any of the other blood serums were dropped into the liquid it remained perfectly clear and transparent. Where the blood of a horse was treated with salt water the antiserum caused by the blood of the horse gave a telltale ring of opalescence, while all the others remained clear, thus giving a key to the kind of animal to which the original flesh belonged. Although this test has been known for about five years it has only recently been brought to its present perfection.

The only exception to this test is that the blood of a man and the blood of a high class ape give the same results.

THE LONGEST AQUEDUCT IN THE WORLD

The longest of Rome's celebrated aqueducts was fifty-seven miles. New York's Catskill aqueduct will be ninety-five miles long, but the aqueduct which will supply Los Angeles with water, now under construction, will be two hundred and forty miles long and involve some unusual engineering features. That portion of the tunnel which pierces the crest of the Sierra Madre range and which has been drilled through 26,780 feet of solid granite was completed in February.

Of the two hundred and twenty-six miles of conduit, twenty-two miles will be an open, unlined ditch through clay, twenty miles will be a covered ditch lined with cement or rubble, one hundred and thirty miles will be covered conduit of cement, eighteen miles will be tunnelled through rock, ten miles tunnelled through earth, nine miles of stee siphons crossing cañons and two miles of steel flumes crossing depressions. Eventually the conduit will be covered through its entire length.

This will be the longest conduit in the world supplying a city with water. The only other water-works plant comparable with this system in magnitude is the one now being constructed for the city of New York. The Los Angeles system with a daily capacity of 400,000,000 gallons will cost $26,000,000 while New York's with a daily capacity of 500,000,000 gallons will cost $162,000,000. It is estimated that when the system is completed it will irrigate more than 100,000 acres of land, making possible a population of 500,000 people within a radius of twenty-five miles of Los Angeles.

According to reports from Washington electric locomotives will be used for towing ships through the Panama Canal locks. The locomotives will be gear-connected to the track by a middle rail cut into the form of a rack in order to obtain the requisite tractive effort.

ORIGIN OF THE CORAL REEFS

A SUGGESTION BEARING ON THE QUESTION OF THE FORMER MOBILITY OF THE EARTH'S CRUST UNDER THE DEEP OCEANS

BY REGINALD A. DALY

The voyage of the "Beagle" made Charles Darwin not only the great biologist but, as well, one of the ablest geologists of his time. His book on Coral Reefs speedily became famous because it offered the first well-reasoned explanation of those marvellous structures. Almost simultaneously and quite independently, J. D. Dana developed the same theory among the islands of the Pacific. The Darwin-Dana theory demands the slow subsidence of the sea-bottom, to the extent of 1,000 or 2,000 fathoms or even more. The individual areas of sinking were to be estimated by the millions of square miles. This process, on a truly planetary scale, was described as continuing into our own day. In the second half of the last century, Semper, Rein, Murray, Alexander Agassiz, Guppy, and others made detailed studies of numerous reefs and agreed that many of these show clear evidence of recent uplift. Sir John Murray and Alexander Agassiz, the one a member of the most fruitful of oceanographic expeditions, the other with an absolutely unrivalled personal knowledge of the reefs of the three oceans, have specially emphasized the failure of the subsidence theory to explain the "facts of the field."

Atoll reefs are rocky crowns laid on broad platforms, which, in each ocean, have an average depth of about 275 feet of water upon them. The lagoons inside the reefs have average depths of about 200 feet. The crowning reefs are veneers laid upon the platforms. This fact is shown by the general topography of such archipelagoes as the Maldive group in the Indian Ocean. According to Agassiz and others, the same fact is often evident in the case of recently uplifted reefs, where in each case there is a distinct structural break between the modern reef and the rock of the general platform. The existing reefs are always of small thickness and area. In view of the great rapidity of coral growth, it seems clear that the life of the existing reefs began not many thousands of years ago. At the time of their birth the platforms must have been even smoother than they are now, though the oceanic charts show that they are exceedingly smooth today. The general relations may be better understood by reference to the accompanying cross-section of a typical reef-crowned platform.

Section of the composite Ari Atoll in the Maldives. Platform rock shown by cross-lining; coral reefs and calcareous débris by solid black. Horizontal scale is four miles to one inch; vertical scale ten times as large

These facts, which patient surveys of the platforms have only recently made fully apparent, seem to find no explanation on the Darwin-Dana hypothesis of wholesale subsidence of the sea-floor. Nor have the opponents of their view given a satisfactory explanation of the peculiar topographic relation of atolls to their platforms. As a result of studies on the Hawaiian reefs in 1909, the writer has

Northeast horn of Makunudu Atoll in the Maldive Archipelago, showing small area of reef. The light-tinted water is lagoon. After Agassiz

attempted to provide a working hypothesis to meet the case. He bases the conception on facts which were either quite unknown in Darwin's time or not then properly evaluated. Of leading importance are some of the facts derived from quite recent glacial discoveries. The argument is briefly as follows.

With increasing knowledge of the glaciated regions in the southern hemisphere, it is becoming more and more certain that the whole earth was chilled in the Pleistocene (Quaternary) period. The Pleistocene ice-sheets, which have since melted away, had a combined area of at least 6,000,000 square miles. The average thickness of the ice was very probably more than 3,000 feet. The removal of enough water to form that ice tended to lower sea-level all around the globe by at least 150 feet. The gravitative attraction of the ice-caps must have further lowered sea-level in the equatorial seas by amounts ranging from 30 to 50 feet. The net shift of level in the equatorial zone was, therefore, at least 180 feet. Conversely, the melting of the full 6,000,000 square miles of ice must have raised sea-level in that zone by about 180 feet.

The Pleistocene chilling of the equatorial ocean, even if the average surface temperature were lowered only half a dozen degrees centigrade, must have greatly retarded the growth of reefs, for the reef-building polyps cannot long withstand a temperature below 20°C. The February marine isotherm of 20°C. lies but a few hundred miles north of the larger Hawaiian Islands. We may be certain that those islands were not bordered by living reefs at a time when 4,000,000 square miles of ice capped the neighboring continent. Hawaii itself seems to have borne at least one small glacier, the characteristic traces of which were observed by the writer on Mauna Kea at the 12,000-foot level.

Having lost their defending reefs by the temporary change of climate, the Pleistocene islands fell a prey to the enormously powerful breakers of the open ocean. At the rates of erosion actually measured on existing coasts, and within the time fairly estimated for approximate maximum glaciation, most of the Pleistocene oceanic islands (composed of limestone and other soft rock) would be worn flat by the waves. At that time the sea-level was at least 180 feet lower than now. The plains of wave abrasion lay a few fathoms below that level.

With the amelioration of climate the ice-caps of the higher latitudes began to melt, and the surface temperature of the equatorial ocean soon reached the mini-

Pitted and honeycombed elevated reef rock of a Maldive Atoll. After Agassiz

mum point where coral polyps could flourish. These animals speedily colonized the eroded platforms and developed the atoll form as a result of the slow rise of sea-level.

This hypothesis seems competent, therefore, to explain the remarkable flatness of the platforms; their nearly uniform depth of about 275 feet; the crown-shape and small size of the atoll reef; the fact that the reefs are veneers on the platforms; and the formation of their wonderful lagoons.

"As Suess points out, these features can hardly be explained, either on the Darwin-Dana hypothesis or on Murray's hypothesis of solution inside the reef. Murray's conception, that many of the plateaus have been built up by calcareous accumulations on volcanic peaks which, by eruptions, had reached to depths within a few hundred fathoms of the surface, is in ill adjustment with his solution hypothesis. In any case it cannot solve the problem for the vast majority of reef-bearing plateaus.

"Since reef-building corals doubtless flourished in the equatorial seas during the Tertiary period, and there greatly protected island and mainland from wave attack, the development of the smooth floors, on which the existing reefs stand, is not to be ascribed to Tertiary marine erosion. In fact, it is an open question whether the atoll archipelagoes do not represent a highly exceptional set of conditions, such as have very seldom prevailed in the history of the globe. According to the hypothesis here proposed, the essential conditions have included a hollowing (negative) movement of sea-level with subsequent heaping (positive) movement of sea-level, each movement being connected with that rare phenomenon, general glaciation. Atoll-forming periods may have been at least as rare as periods of such glaciation, and it is possible that only since the late Pleistocene has the first atoll archipelago come into existence. Single small atolls might have been formed at any time since the reef-building corals were evolved, but such groups of atolls as the Maldives, with their

peculiar relation to the underlying plateaus, seem to demand special shifts of level. For explanation of existing atolls and barriers the preference is here given to a moderate tumular movement of the ocean, rather than to the enormous crustal displacements implied in the Darwin-Dana hypothesis."*

The suggested hypothesis has one obvious and important bearing. If it be correct, the existence of atolls in the "coral seas" can no longer be regarded as a proof that the Pacific basin at least is of recent origin. Belief in its antiquity is thereby facilitated, as, indeed, that belief seems compelled by many principal facts in geology.

*R. A. Daly, *American Journal of Science*, Vol. 30, 1910, p. 307.

PROTECTIVE COLORING

It is a matter of general observation that birds and animals have a dark color on their backs and oftentimes are very light in color on the under side of their bodies, but an artist named Thayer is probably the first person to point out what naturalists had failed to discover,—that this was really a matter of protective coloring. At first sight it does not seem possible that the intense white on the breast of a bird as compared with the dark back and upper part of the wings could serve as protective coloring, but Mr. Thayer has made an experiment which shows conclusively that this is a fact.

Three small objects were placed horizontally on wires a few inches above the ground. They were earth color on top and two were painted white on the under side blending to a brown on the sides, while the other one was painted earth color all over. When viewed from a little distance, the two that were colored white below disappeared from sight, while the other one stood out in strong relief and appeared much darker than it really was.

A similar experiment was made on a lawn. One of the objects was painted green on top but white on the underside, and the other one was painted green all over. As the observer moved away from them, the former soon became invisible while the latter became conspicuous.

A PERMANENT AURORA

Many people have no doubt observed that on some nights the sky is much brighter than on others although there is no appreciable difference in the brightness of stars, and in fact occasionally on moonless nights, even when the sky is overcast, there is a general illumination of the sky, increasing towards the horizon, which is known as "earthlight."

It is true that a certain amount of the light of the sky on a starry night is due to diffused starlight, but it is equally true that when the sky is clouded and not a star to be seen, impressions have been made on a photographic plate after half an hour's exposure.

Mr. Yntema of the Astronomical Observatory in Groningen, Holland, who has recently issued a memoir on this subject agrees with other scientists that this phenomenon is the effect of a permanent aurora which overspreads the whole sky and presumably is common to all parts of the world. The auroral character of this light appears to be established by the fact noted by several competent observers that the characteristic green line of the auroral spectrum, generally attributed to the element krypton, may be observed in all parts of the heavens on almost any clear night.

CEMENT FLOORS IN PULLMANS

A feature of the newly equipped trains in the Chicago limited service of the Baltimore & Ohio Railroad is that the new coaches are provided with cement floors. Although cement flooring for passenger cars was suggested years ago on the grounds of durability and cleanliness as well as to safeguard against fire, the idea was rejected on the presumption that vibration would cause it to crack.

THE GNOME ENGINE DESCRIBED

IT WAS DESIGNED FOR USE IN AIR-SHIPS AND HAS GREAT POWER AND LITTLE WEIGHT—AS EXTRAVAGANT TO MAINTAIN AS IT IS EXPENSIVE TO BUILD

Reports of recent aviation meets have so often mentioned the Gnome motor that it seems timely to briefly explain the salient peculiarities of this type of aëroplane engine. As is well known, this is the engine used by Grahame-White in his flights.

To explain clearly the fundamental differences between the ordinary and the Gnome engine, consider first the parts and operation of a gas engine, as shown diagrammatically in Fig. 1. The cylinder C and frame F are stationary. The shaft S revolves in bearings which are fixed in the frame F. The crank K is on the shaft S and is keyed to it so that both revolve together. When the proper explosive mixture is introduced between the piston P and the head H of the cylinder C and then ignited, the piston P is driven to the right, which pushes the rod R and the upper end of the crank K to the right causing K to revolve about the shaft S into the position shown in Fig. 2. As S is keyed to K the shaft S must revolve with the crank K. The shaft S is attached to the propeller or whatever it may be that the engine drives.

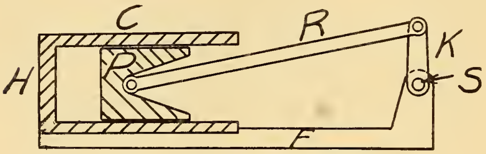


Fig. 1

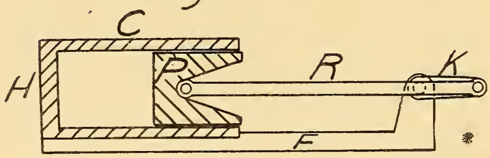


Fig. 2

If now, as in the Gnome motor, the shaft S and crank K are stationary while the frame F and its attached cylinder C are free to revolve about the shaft S, the parts are initially in the position shown in Fig. 1. Suppose the proper mixture is now exploded between the piston P and the head H as before. A pressure is transmitted through the rod R to the crank K as before, but this crank is now stationary while the cylinder C and frame F are free to revolve. The effect of the pressure, however, will be to cause the piston P to move to the right relatively to the cylinder C. The only way this can be accomplished is for the cylinder and frame to revolve about the shaft S into the position shown in Fig. 3. In this case, as the cylinder revolves, the propeller must be attached to the cylinder instead of to the shaft as in the preceding case.

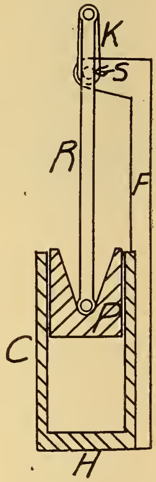


Fig. 3

In the Gnome motor seven cylinders are used spaced equally about a circle as shown in Fig. 4. In this figure the crank case has been removed to show more clearly the arrangement of crank and rods. It will be noted that all the rods are attached to the same crank. This causes each piston to occupy a different position from any of the others relatively to its cylinder. This makes the operation smoother because the mixture in no two cylinders is being ignited at the same instant. The fuel is introduced from the carbureter into the crank-case and from thence is introduced into the cylinder through automatic valves in the piston.

The small radial rods shown in Fig. 5 actuate the exhaust valves located in the cylinder head. These exhaust valves allow the burned gases to escape.

Some of the advantages of the Gnome motor over the ordinary type may be outlined as follows. In the ordinary gas engine, owing to the piston in one cylinder receiving an impulse from explosion only once in two revolutions instead of twice in each revolution, as in the ordinary steam engine, either a very heavy flywheel or a large number of cylinders must be used in order to secure a uniform turning effort throughout two revolutions. A large number of cylinders means a long crank shaft with many cranks, bearings, and frames because the cylinders must be placed side by side along this shaft. In the Gnome motor all the seven cylinders are attached to a ring surrounding the shaft and the rods are all attached to the same crank, thus effecting a material saving in weight and space.

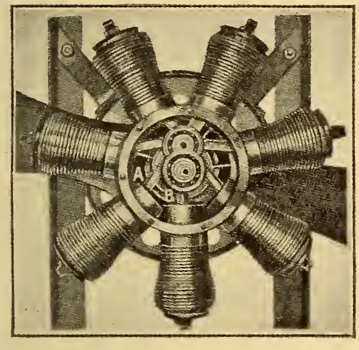


Fig. 4. End view of Gnome Motor —Courtesy of *Power and the Engineer*

In all gas engines it is necessary to artificially cool the cylinders to prevent their overheating from the explosions of gas within them. This is generally accomplished by circulating water about the cylinders and then cooling the water in radiators. The cylinders of the Gnome engine revolve so rapidly through the air that the water-cooling may be dispensed with, their motion in the air being sufficient to keep them comparatively cool. The ribs on the outside of the cylinders in Fig. 4 are to promote rapid radiation. The air-cooling feature further reduces the weight over that of the water-cooled motors of other types. This motor is sometimes made double with fourteen cylinders as shown in Fig. 5. In this case there are two engines used, one directly behind the other with the cranks 180 degrees apart and the cylinders in one set opposite the spaces in the other. This arrangement both allows a free circulation of air about all cylinders and lessens the length, thereby saving weight.

The seven cylinder Gnome engine weighs 167 pounds and develops 45 to 47 horse-power at 1000 revolutions per minute. It has proved its reliability by securing all long-distance and endurance records. The fourteen cylinder Gnome engine weighs 220 pounds and develops nominally 100 horse-power.

The cylinders have a bore of 4 3-10 inches and a stroke of 4 7-10 inches. The most unusual feature about the cylinders is that, instead of being cast as ordinary engine cylinders are, they are turned out of a solid bar of nickel-steel. The walls of the cylinders are a little less than 1-16 inch thick. Each cylinder has twenty-two fins turned on its exterior which both strengthen and help to cool it by exposing more surface from which to radiate heat. It is oiled by pumping pure castor oil into the crank-case. This lubricates all the bearings and at the same time the

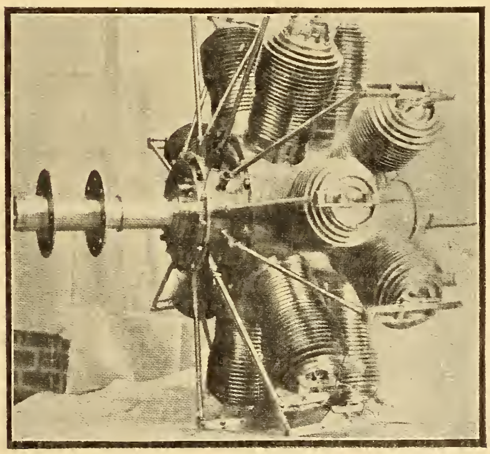


Fig. 5. General Assembly of Gnome Motor —Courtesy of *Motor Age*

oil flies outward due to centrifugal force and lubricates the cylinder walls. A large amount is lost by being driven out of the cylinders by the exhaust. The makers estimate that 7 pints of lubricant are needed per hour for the 100 horse-power engine but this is largely exceeded. The gasolene consumption for fourteen cylinders is from 11 to 13 gallons per hour. L. E. M.

CALIFORNIA OIL AND THE PANAMA CANAL

Advance chapters of the United States Geological Survey's annual report regarding the production of petroleum for 1909 give the following information:—

The total output for the world in 1909 was 297,413,791 barrels, of which the United States produced 182,134,274 barrels or 61.3%. California alone furnished 54,433,010 barrels or nearly 30% of the entire amount produced in the United States.

The output of California in 1905 was 32,427,473 barrels as against 54,433,010 barrels in 1909 or an increase of 68% in the four years.

The production of the "Gulf" field consisting of Texas and Louisiana, decreased in the same period from 36,526,323 barrels to 11,912,058 barrels or 67.5%

The output of both the "Gulf" and "Mid Continent" fields, consisting of Texas, Louisiana, Oklahoma, Kansas, Missouri, Colorado, Utah and Wyoming for the same period increased from 49,062,100 barrels to 61,716,980 barrels or 26%.

If the above rates of increase and decrease should continue for the next four years, or until the probable opening of the Panama canal, California would then be producing over 91,000,000 barrels annually against 3,700,000 barrels for Texas and Louisiana, or 25 times as much. Or comparing California's probable output with the probable output of the rest of the United States west of the Mississippi River, which would then be producing annually 77,700,000 barrels, California would still be 17% ahead.

In view of the above it would seem to be safe to predict that the natural outlet for this tremendous production of oil, would be either as crude petroleum or fuel oil, the residuum left after the lighter oils have been removed by partial distillation, shipped from Californian ports through the Panama canal to the north Atlantic seaboard cities, there to be used as fuel in competition with coal, the tendency being to keep the price of oil equal to and possibly less than the corresponding heat value in coal, especially if coal continue to advance in cost along the New England coast as it has done during the past few years.

The Panama canal will also tend to develop the liquid fuel resources of Mexico, Peru and Chile, all of which countries have large quantities of petroleum along their western coasts, from the fact that their actual distance by water from the north Atlantic coast of the United States will be less than that of any Californian port after the canal is completed. B. R. T. C.

BIOLOGICAL RADIO-ACTIVITY

The interesting discovery has recently been made that radio-active rays technically known as *beta* and *gamma* are given out by an organic substance called oxyburseracin. This latter is made by treating one of the products of the rosin of the myrrh tree with hydrogen peroxide. The substance loses its radio-activity in about nine months. This is the only case known where a substance obtained from animal or vegetable life is radio-active. If the rays are being given off by the organic compound itself some of the atoms present must be decomposing and the phenomenon is of vital importance with regard to our knowledge of the composition of matter. It is probable, however, that the rays are due to the presence of small amounts of some radio-active substances, such as radium salts, which the tree has got from the soil. E. B. S.

HORSE-POWER REQUIRED FOR ROLLING STEEL RAILS

The largest and most modern mill for the production of steel rails is located at Gary, Ind., and has a capacity of 4,000 tons of rails per day of twenty-four hours, or sufficient to equip more than thirty miles of single track with eighty-pound rails. The power to operate the plant is provided almost entirely by large gas engines utilizing the by-product gas from the blast furnaces. The motive power of the roll mill is supplied entirely by electric motors of the three-phase induction type, supplied at 6,600 volts. The ingot as it is fed to the rolls weighs over four tons and has a length of five and one-half feet. Eighteen passes through the rolls are required to reduce it to its final form, in which it attains a length of nearly 140 feet. The lighter passes are driven by motors of 2,000 horse-power, capable of operating for one hour at 3,000 horse-power and for momentary periods at from 5,000 to 7,000 horse-power. For the heaviest passes motors rated at 6,000 horse-power are provided. These are capable of operating for one hour at 9,000 horse-power and can give momentary outputs of from 16,500 to 20,500 horse-power. These tremendous momentary capacities are obtained by the use of very heavy revolving parts which take the place of fly-wheels. In normal operation the maximum power required at any single pass is 8,350 horse-power, so that an immense surplus is available for short periods in emergencies. With the mill running at full speed the entire cycle of rolling operations requires less than six minutes and the ingots follow each other at intervals of about one-half minute. W. E. W.

Wine or cider if exposed to the air becomes sour. This souring is caused by the presence of certain bacteria.* If the wine or cider in thin layers is allowed to run slowly past a lamp that gives out ultraviolet rays these bacteria are killed and therefore the souring process is consequently arrested. The layers in the case of white wine may be very much thicker than those of the cider because the latter is not so transparent to the rays that destroy the bacteria. The "working" or fermentation of preserves could probably be prevented by these same rays. E. B. S.

*Which promote chemical action in some unknown way.

CORROSION OF IRON IN CONCRETE

It is well known that if iron be surrounded with another substance and then subjected to the action of an electric current from some external source, that if the current flow in the right direction the iron will be deposited on the surrounding substance in a manner analogous to the common process of plating. The iron is not, however, deposited as, for instance, is silver in the silver plating process, in the form of pure iron but is found irregularly distributed through the surrounding medium and is generally in the form of an oxide of iron commonly called rust. This action is called electrolysis. It has been commonly assumed that if the substance surrounding the iron be concrete the iron would not deteriorate. In the past this has been true, owing to the absence of electric current. The increasing use of electricity has introduced a factor which may cause extremely rapid disintegration under certain conditions. A series of tests have been made in the laboratories of the Massachusetts Institute of Technology to obtain data on this electrolytic action.

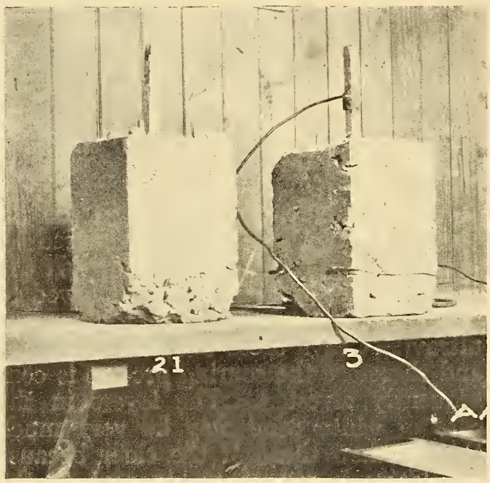


Fig. 1

Bars of steel were embedded in concrete as shown in Fig. 1. The blocks were covered so that the current flowed through at least three and one-half inches of concrete. The blocks were then immersed in a salt solution and the tests were continued until disintegration took place or the current ceased to flow. The blocks split as shown in Fig. 2. The result obtained is that if unstressed iron in concrete is subjected to a current as small as .015 ampere flowing from the iron to the concrete, rapid decay is in-

Fig. 2

evitable no matter what the thickness of the protective coating of concrete may be.

Other tests were made on iron under stress in a salt solution. The result seems to be that the greater the stress which the material is undergoing the less rapid is the corrosion. It is interesting to note that the experiments of Hambuechen and Burgess at the University of Wisconsin show that an unprotected piece of metal when stressed is more rapidly corroded than when free from stress.

L. E. M.

The New York *Sun* makes the surprising statement that the increase in manufacturing establishments throughout the United States during the five years previous to the industrial census in 1905 was 2,863 of which 1,613 were credited to Manhattan and The Bronx. This means that almost, or quite, one half of the total increase in the United States took place in New York City.

SCIENCE CONSPECTUS

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THE ULTIMATE STRUCTURE OF THINGS

A BRIEF EXPOSITION OF MODERN IDEAS CONCERNING THE CONSTITUTION OF MATTER, IN THE LIGHT OF RECENT DISCOVERY

BY D. F. COMSTOCK

IV

Résumé

In the first three articles, the ultimate structure of matter, according to modern ideas, was outlined in so far as it involved the *mutual relations* of atoms and electrons. In the present article, certain ideas will be described which seem to involve the conditions existing *within* the atom.

Radio-Activity

There is a remarkable group of substances, of which radium is perhaps the most striking member, which emits rays continuously without obtaining any energy from their surroundings. In the case of radium it is now known with considerable surety that the rays would only fall off to about half their present intensity in two thousand years. This extraordinary action goes under the general name of "radio-activity" and the substances which emit the rays are known as "radio-active substances."

The Three Rays.—The rays emitted are not all of the same kind but are composed of three distinct types, each with definite characteristics of its own. It was thought convenient in the beginning to designate these rays by the first three of the Greek letters, and they are therefore known as the *alpha-rays*, the *beta-rays*, and the *gamma-rays*.

The Beta-Rays.—There is now no reasonable doubt that the beta-rays consist of a stream of electrons coming out of the substance like bullets from a Gatling gun. The most surprising thing about these rays is the enormous velocity of the electrons. Their speed is almost equal to that of light, namely, one hundred eighty-six thousand miles a second. This inconceivable velocity is measured indirectly, but by methods which make it almost certain that the result is correct. This speed enables the rays to penetrate a plate of metal as thick as an ordinary book cover.

The Alpha-Rays.—Within the last two years it has become practically certain that these rays consist of a stream of *atoms of the element helium*. This is a truth which could not have been predicted by any one when first the rays were discovered and it is very surprising. The helium atoms have each a double

positive charge. This means, of course, as will be remembered, that each atom has lost two electrons. The atoms of the stream have a velocity about one-tenth that of light, that is, they are traveling at a speed of about eighteen thousand miles per second. This is not nearly so fast as the electrons in the beta-rays, but it must be remembered that the atom of *hydrogen* is two thousand times as heavy as an electron so that the atom of helium, whose "atomic weight" is four, is about eight thousand times as heavy as an electron, and thus, although the helium atoms of the alpha-rays are moving more slowly, their energy is much greater than the beta-ray particles, the electrons, because of their far greater mass.

As a matter of fact, this energy is so great that a single "alpha particle," that is, a single atom of helium, when it strikes certain substances, will cause them to phosphoresce (or more properly fluoresce) for an instant. This enables us actually to see the effect due to the impact of a single atom and gives us the first case in the history of science where any effect caused by *one* atom has been observed.

The Gamma-Rays.—These rays present a definite contrast to the other two just mentioned because they do not appear to consist of particles at all. Although we are far surer of the nature of the alpha- and beta-rays than we are of the gamma-rays, still it is highly probable that the latter consist of wave impulses somewhat similar to light or X-rays.

The connection between the beta-rays and the gamma-rays is probably similar to that between the bullet and the sound in the case of a gun. Both the bullet and the sound of the explosion travel away from the mouth of the gun, but the bullet is *a moving object* while the sound is a disturbance, a wave impulse, that is, in the air. In the same way both the beta-rays and the gamma-rays come out of the radio-active substance, but the beta-particle is a moving electron while the gamma-rays are probably wave impulses in the "ether." Both rays, however, like bullet and sound, are due to the same cause.

Cause of Radio-Activity.—It is now generally believed that the cause of radio-activity is none other than the actual breaking up of the atoms of the substance radiating. The radium atom explodes, like a bomb, into three "pieces" and the energy of the explosion gives each "piece" a high velocity. A beta-particle (an electron) is given off, an alpha-particle (a helium atom) is given off, and a *new atom*, an atom that is of a *new element*, is left behind.

We have then, in radio-activity, a case of natural alchemy, but since it has been found impossible so far to hasten or retard the process artificially, the knowledge of radio-activity would not have helped the old alchemists in their quest.

Successive Disruptions.— The radium atom appears in fact to be a member of a chain of "explosive atoms" for the atom left behind after the explosion is itself radio-active, that is if given time it will itself "explode" and give off another helium atom. The chain has been followed out through nearly a dozen elements, and part of the chain is shown in Fig. I.

Not A Chemical Change.—It must be borne in mind that the change accompanying the process of radio-activity is *not a chemical change.* As will be remembered, it was carefully stated earlier in these papers that a chemical change involves the *regrouping* of the atoms to form new molecules. This does not affect the integrity of the individual atoms but only their relations to their neighbors. In radio-activity, on the other hand, we have changes which involve *the actual disruption of an atom.*

Inter-Atomic Energy

When coal is burned we get energy from the attraction existing between the atoms of carbon (coal) and the oxygen atoms of the air, and in general it should be evident that whenever there are strong attractions or repulsions between different atoms, there is a possibility of obtaining energy by allowing these forces to act. The energy developed in radio-activity is therefore similar to the "heat energy of coal" in one respect, but quite

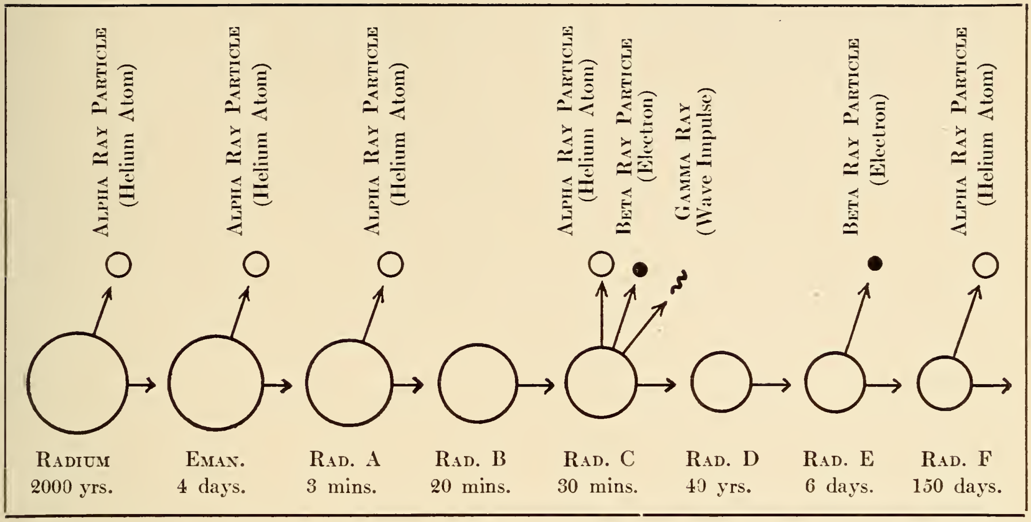


Diagram representing symbolically the transformation of part of the radium chain of elements. The first circle represents a radium atom which when it "explodes" throws off an atom of helium and what remains becomes an atom of another element called, for want of a better name, "radium emanation." This process is repeated through the chain, "Radium A," etc., following.

The times indicated below the circles give an idea of what might be called the "explosion frequency." Thus in the case of the atoms of radium, the rate is such that about half of all the atoms corresponding to any piece of radium would be transformed in 2,000 years. In the case of the next element, the time for half to be transformed is only about four days. This time may be called the "life of the element" in each case. It is now supposed that the well-known common elements are simply those with very long "lives."

distinct in another respect. The radio-active energy does have its origin in the forces acting within the substance, but they are not the forces acting *between* the atoms, as is the case with all chemical energy, but rather the forces acting *within* the atom, the so-called "*inter-atomic forces.*" We can therefore say in one statement that all the energy now made use of in the world, all the energy due to chemical action and the burning of fuel, is of the *extra-atomic* variety while the energy of radio-activity is something quite new to us, since it comes *out* of the atom, so to speak, and is therefore *inter-atomic* energy.

Enormous Quantity of Inter-Atomic Energy.—One of the most remarkable facts about these *inter*-atomic forces is their enormous size compared with the *extra*-atomic forces of chemical action. The slowness of the radio-active changes tends to conceal this fact, but it is nevertheless true.

The energy given off by radium ultimately becomes heat and this heat has been directly measured a number of times. Since the radium would only be half gone in two thousand years, a simple calculation shows that *the total energy given by a given amount of radium and its products during transformation is about a quarter of a million times the energy to be obtained by burning an equal weight of coal.* To make this statement a little more vivid, the fact might be noted that the S. S. *Mauretania* burns something less than five thousand tons of coal during one ocean passage, and from the above figures this would be equivalent to *four pounds* of radium and its products.

The Radio-Active Elements

It must be mentioned here that there is nothing remarkable about the radio-active elements *except* their *radio-activity*. In other respects they resemble closely the well-known elements. For example, referring to Fig. 1, radium itself belongs to the same chemical family as barium and behaves chemically almost exactly like barium. The next element, the atoms

of which are formed from the "wreckage" of the radium atom, so to speak, is a gas, called "radium emanation," and resembles the gas argon, which is one constituent of the atmosphere. The next element, "radium A" so called, is a solid substance.

The atomic weight of radium is about 226, that of "radium emanation" is about 222, and that of "radium A" about 218. These numbers are in harmony with the fact that the alpha-particle (the helium atom) which comes off at each explosion has an atomic weight of 4, so that each of the above elements has a weight of 4 less than the element from which it sprung. The first three elements of the chain in Fig. 1 do not, as it happens, give off beta-rays, but the change in weight, due to an electron lost, would not sensibly change the atomic weight.

Are all the Elements Radio-Active?

There is considerable reason to believe, although as yet no absolute proof, that all elements are decomposing in the same way, or in other words, that radioactivity is a universal property of all matter. This means, of course, that in the case of the well-known "permanent" elements the process is so slow as not to be noticeable. Already potassium has shown signs of being radio-active and as methods of measurement become gradually more delicate, it is probable that more elements will show their activity.

Evolution of the Elements

The probability that all elements are to some degree radio-active has led to the general conception of what is called the "evolution of the elements." According to this idea there is a slow forming of the lighter elements through the disintegration of the heavier ones. The well-known elements of our acquaintance are to be considered as merely those whose average "life" is so great as to be, from a human point of view, permanent. If this concept be a true one, if the atoms of any element are descendants, as it were, of the atoms of heavier elements, then it is not difficult to see in a general way why all the remarkable relations should exist between the elements which have long been known.

One objection which has been raised to this view is that, did such evolution exist, it must have completed itself years ago so that only the lighter elements should now exist. There are, however, some faint indications that under conditions greatly differing from terrestrial, conditions which exist in the hotter stars, the process may be going the other way, may be going in a direction, that is, which involves the building up of the heavier elements out of the lighter ones. To go further than this one remark, however, would lead too far into speculation.

Atomic Structure

Although the study of radio-activity has opened the door into the knowledge of inter-atomic phenomena wide enough to see the enormous energy contained within the atom, it has not opened it wide enough as yet to give us any *definite* idea of the details of atomic structure.

One or two very general remarks can, however, be made. In the first place, electricity plays an important part as a building material for atoms and the inter-atomic forces must be largely electrical, must be largely, that is, the same kind of force that pulls bits of paper to a comb. Whether *all* inter-atomic force is of this nature is a question which cannot now be answered.

Secondly, we can say without much chance of ultimate contradiction that the atom is a very "open work" kind of an affair, very much more "porous" in other words than the appearance of the vast aggregates of atoms which we know as "bodies," would lead us to believe. It was stated further back that some of the beta-particles (electrons) from radium, traveling with nearly the velocity of light, go straight through a piece of metal as thick as the average book cover, and it needs but a very short calculation to show that this means that the electron penetrates more than a million atoms one after the other. It must be remembered that in a solid substance the atoms are quite near together so that such a flying

electron has no chance of traveling entirely in the *space between the atoms* during its whole passage through the metal. If the atom is made up almost entirely of electrons, then it is easy to show that, on the average, the electrons must be as far apart compared with their size as the planets in the solar system. This seems absolutely absurd, but it must be remembered that our feeling of absurdity comes from our almost uncontrollable tendency to compare everything we learn to the things we see and hear in everyday life. The mighty distances of space, which astronomy compels us to contemplate, are no more difficult to conceive than are these remarkable attributes of the minute ultimates which we know as atoms.

Problems for the Future

It was said in the very beginning of these papers that the general history of physics would lead us to believe that the modern ideas here set forth, were probably right as far as they went, although they would surely appear inadequate to future critics. No one appreciates their inadequacy more than the researcher himself, for on all sides of him he sees unexpected and baffling phenomena whose cause he cannot now even guess at. The "cock sureness" often attributed to scientific men is sometimes found in the works of popular writers, but very seldom, indeed, among the scientific workers themselves.

In the present articles a somewhat final tone has been unavoidable because qualifications require space and sufficient space was not to be had. I should, however, be leaving a wrong impression if no mention whatever were made of the questions and problems which lie before us and which never allow us to forget the extraordinary complexity of nature. Such mention, however, must be very brief and confined largely to the question form.

1. Is the difference between a liquid and solid substance *solely* a question of crystalline structure, that is of orderly arrangement of the molecules, or is there some other element which enters? The discovery of so-called "liquid crystals," that is small particles of *liquid* which have an orderly molecular structure, renders it probable that there *is* some other cause which helps to make a difference between the two states.

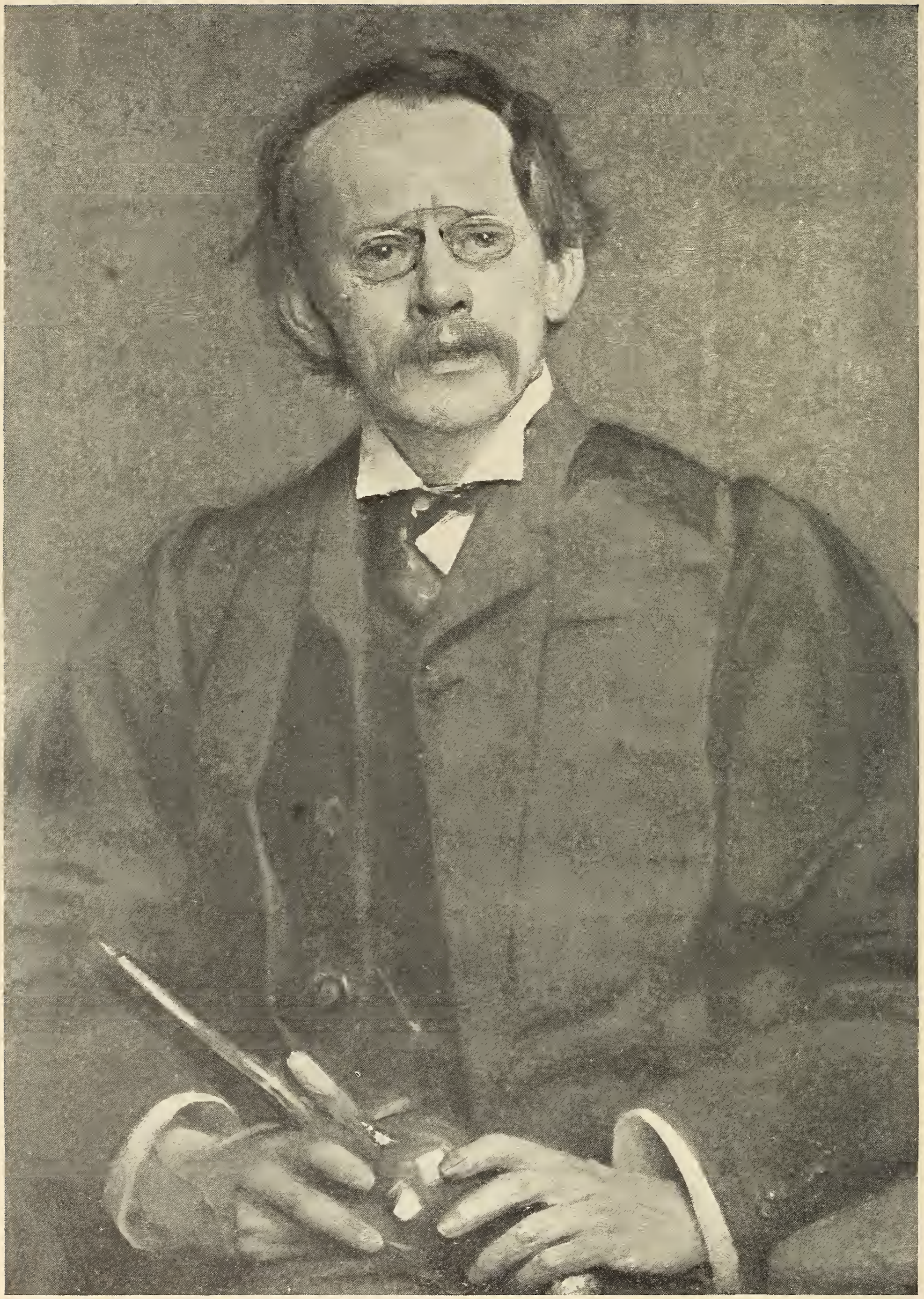
2. Is there a *positive* electron similar to the negative one? We have as yet been unable to get the slightest "glimpse" of it and probably it does not exist but the *structure* of the "positive electricity," which we know must be in the atom, is as yet a completely unsolved problem.

3. What is the general structure of the atom? Do negative electrons together with the as yet undiscovered positive ones, make up the whole of the atom, or is there some other kind of structure as yet unguessed?

4. What causes the "explosion" of the atom which we are bound to believe occurs in radio-activity? Why, when an atom has preserved its integrity for tens, hundreds or thousands of years, should it suddenly, in a billionth of a second, "explode" and fly apart forming two new atoms? Is there some type of intrinsic instability which develops, or does some outside cause pull the trigger, so to speak?

5. Shall we ever be able artificially to hasten this breaking up of atoms and so set free the enormous quantities of "inter-atomic energy" which has been shown to exist in some substances and probably (on the grounds which cannot here be set forth) *exists in all?* (It is to be remembered that the estimated inter-atomic energy of coal is more than a million times its chemical energy, the energy we now use.)

6. We have spoken of the great process of atomic disintegration. Is there going on anywhere in nature the reverse process, the building up of heavy atoms out of light ones, and if so, where does the vast quantity of energy come from that must obviously be put in during such building up, since it *comes out* during the breaking down? We have spoken of the hotter stars as possessing interesting possibilities for research in this direction. Much can be told as to their condition by studying their light.



SIR J. J. THOMSON
The most eminent living discoverer in the domain of electricity and its relation to matter
[From a painting in the Cavendish Laboratory, Cambridge, England]

7. What is the relation of the life process to atomic and molecular structure? Two facts are to be immediately noticed in this connection; first, that all the substances which carry on or are closely associated with the "life process" are substances with enormous molecules, that is molecules which contain dozens or even hundreds of atoms, and second, that these large molecules are extremely unstable, that is, very susceptible of change, and are thus easily modified through the forces of their environment. The ceaseless metamorphosis which the life process implies, could not go on without this sensitiveness to environment.

8. What is the relation between the entity which we call "energy" and matter? Radiant energy leaves the sun eight minutes before it reaches the earth and during this time it exists in a totally disembodied state, that is, quite independent of matter. In general we find energy associated with matter but even then, some of its properties are singularly similar to those of energy in its radiant form.

Is radiant energy really energy of motion in some medium, the ether, or is it an entirely independent entity which can exist in empty space?

We might go on almost indefinitely with questions like these but the few suggestions here given must suffice.

The Discoverers

The men who have advanced our knowledge of the constitution of matter have, of course, been of every nationality, but if one man's name should be mentioned more than any other in connection with modern ideas respecting electricity and matter, it should without doubt be the name of Sir J. J. Thomson of Cambridge University, England. Thomson and the group of men of whom he is the leader have been making one discovery after another for more than two decades and the Cavendish Laboratory is now unquestionably the greatest world center of physical research.

Among the many other names which could be mentioned are those of Rutherford, one of J. J. Thomson's first students and unquestionably the greatest living authority on radio-activity, Becquerel, and M. and Mme. Curie.

It is difficult not to wax over-enthusiastic in writing of these men and the many co-workers whom we have not mentioned. At the beginning of the twentieth century they represent a grade of genius not surpassed if even equaled in any other domain.

Books, Etc.

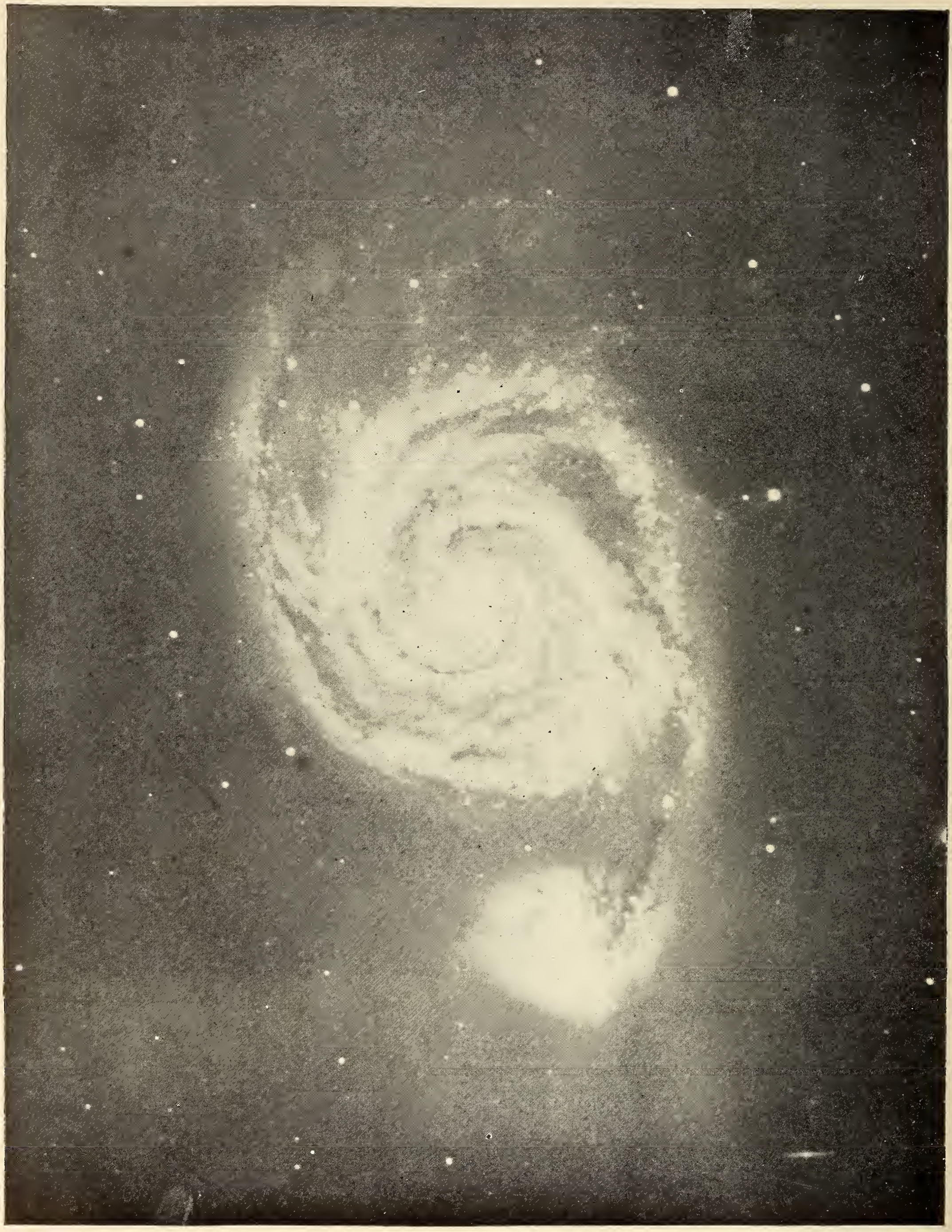
The foregoing articles have of course been unsatisfactory in many ways and it will be well in closing to name several books in which those who are interested may find information. "The New Knowledge," R. K. Duncan, New York, A. S. Barnes & Co., a book written in popular style but containing no misstatements. Very "readable." "The Electron Theory," E. E. Fournier d'Albe, Longmans, Greene and Co. Also popular. List of references in back. "Electrons," Sir Oliver Lodge, London, George Bell & Sons, New York. The Macmillan Co.

The books are named in the order of increasing "difficulty" if any of them may be called difficult at all. The great work of a far more advanced nature is, "Conduction of Electricity through Gases," J. J. Thomson, Cambridge, England. University Press.

STREET RAILWAY ACCIDENTS

The statistics of street railways show that there is a large increase in the number of accidents when box cars are taken off and open cars put into service. Where a careful record is kept of all accidents, a warm day in early spring, when open cars have been run, can be picked out simply by the largely increased number of accidents. One of the great advantages of the pay-as-you-enter car is that the number of accidents is very largely decreased owing to the constant presence on the platform of the conductor. L. E. M.

In the March number we stated that an error of a second in time corresponded to an error of two and a half miles in the position of the ship. It should have been one-quarter of a nautical mile.



Messier 51, in the constellation of Canes Venatici, photographed by Ritchey with the sixty-inch reflector, April 7–8, 1910. Exposure, 10¾ hours. About 500 nebulous stars are shown in the convolutions of this nebula (this is a longer exposure than the one shown in the Astrophysical Journal illustration). This is the celebrated "Whirlpool Nebula" of Lord Rosse, discovered by him visually (to be a spiral) about sixty years ago, and the first spiral nebula to be discovered.

MARVELS OF THE GREAT TELESCOPE

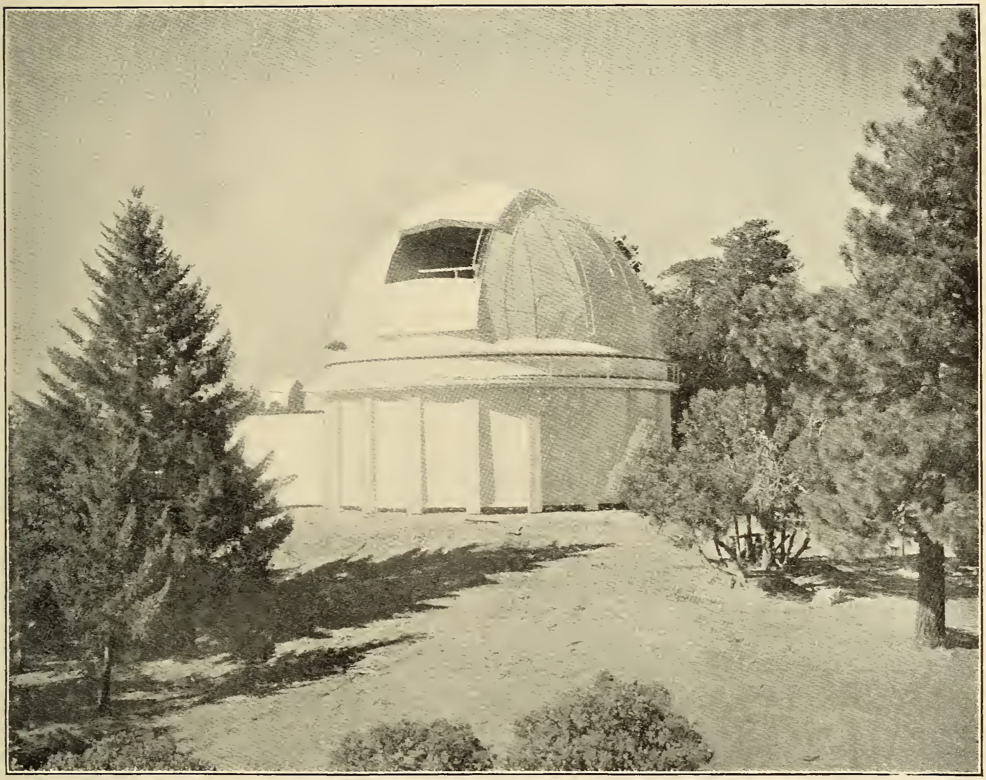
PROFESSOR GEORGE W. RITCHEY TELLS THE SOCIETY OF ARTS ABOUT THE 60-INCH REFLECTOR ON MT. WILSON AND SHOWS WONDERFUL ACHIEVEMENTS IN CELESTIAL PHOTOGRAPHY

The members of the Society of Arts and their invited guests had a wonderful treat at the 676th meeting of the Society, Friday, March 24, in the pictures presented by George W. Ritchey, who spoke of modern photographic work with the telescope, and in particular of that at Mt. Wilson with the 60-inch reflector. It was the presentation for the first time in this city of some of the most striking productions of the camera of the astrophysicists, and only a few of his auditors were aware that it was the speaker himself who had gathered, adapted and invented, and that the mechanical work and much of the chemical, making such results possible, was for the greater part, of his own devising and carried out with his own hands. The introduction of the speaker by Prof. Charles R. Cross, head of the department of physics, M. I. T., who presided in the place of Doctor Maclaurin, was an epitome of the story of astronomical photography. The speaker called attention to the fact that it was at Harvard College observatory that the first celestial photographs were taken. This was by Bond some time in the fifties, but the cumbersome wet plate method was impracticable. Touching on the work of Rutherford and Draper in the interim, the story came again to the same observatory, where, with the advent of the dry plate the work was revived, and the advantages of photography applied to astronomy. Abroad, in the hands of Roberts and others, much admirable work had been done, but of recent years the great institutions of Lick, Lowell and Yerkes have been leading the world in this art.

Prominent among the workers developed by the new science is Professor Ritchey, who applied the color screen to large work and with the great Yerkes telescope showed what marvels could be accomplished. He then began with the construction of mirrors, finishing one of two feet diameter for the Yerkes observatory which was a revelation in the clearness of its work. He then constructed the five-foot mirror for Mt. Wilson, and has in hand a hundred inch for the same institution. "From the fact that the optician must wait at times for the manufacturer," said Professor Cross, in closing, "we are indebted for the presence of Professor Ritchey tonight."

In beginning his address Professor Ritchey noted that the subject of the photography of the heavens is so vast a one that he could discuss but two or three phases of it. These were the coming of the reflecting telescope to its own, its superiority and some of its results in the photography of globular stars, clusters and nebulæ. He noted that the same kind of rapid and sensitive plates are used to catch the stars and nebulæ as for instantaneous work of the ordinary kind; but the exposures for celestial objects are not the tenths or hundredths of seconds used in portraiture or landscape, but extend over hours, or even days. For the latter, of course it may be necessary to take the plate out of the telescope and return it there on some subsequent occasion, perhaps days afterwards, and yet replace it so accurately that the star disks in the new setting will be absolutely in the same spots as in the old. He outlined the mechanism whereby the telescope is made to follow the stars in their paths, and explained the most modern refinements of the controlling clock, which is set in a room of even temperature beneath the ground, air-proof and dust-proof, conveying its impulses, that measure the time to within a hundredth of a second a day, to the driving machinery of the instru-

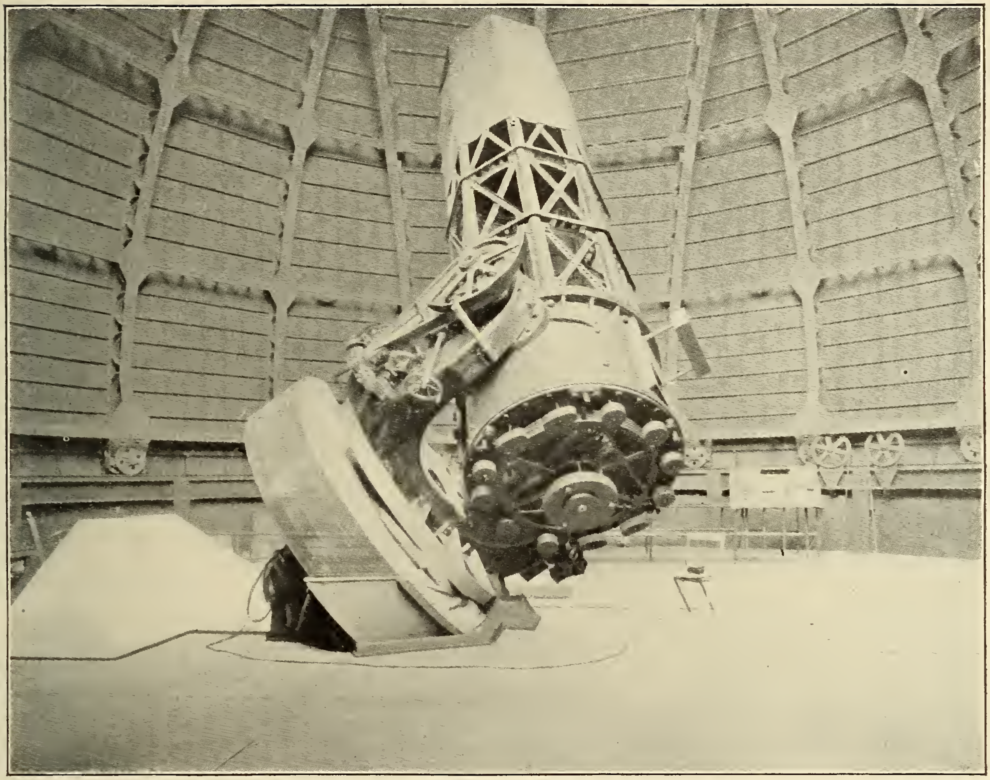
Great Nebula in Andromeda, photographed by Ritchey with the twenty-four-inch reflector, Yerkes Observatory, September 18, 1901. Exposure, 4½ hours. The sixty-inch reflector photographs show that the dark spiral rifts extend all the way in the central nucleus, and that the larger rifts are most remarkably similar in their appearance, and in their peculiar curdled, flocculent structure, to the dark rifts which Professor Barnard has photographed in the Milky Way.



Steel buildings and dome for the 60-inch reflector

ment itself. So delicate is this control and so well regulated is the movement of the telescope that it is more accurate than the apparent motions of the stars themselves. These are affected by refraction which varies with the altitude above the horizon, and superimposed on the refraction are the inequalities of the atmosphere, so that there are always tremors in the air that it is impossible to avoid. "The light of the star," said the speaker, "comes for a hundred or a thousand years unharmed through space, but in the last hundredth of a second of its flight, it suffers great injury." So long as atmospheric inequalities are minute in their disturbing influence it is possible for the astronomer to overcome them. This is done by having the observer at the telescope watch continually some star, and by keeping it true to certain wires in his field of view, maintain the photographic plate in absolutely the same relation to the stars that he is catching. The star that the observer watches is one a little aside from the photographic field, and by means of a double motion plate carrier, very delicate in its adjustments, the corrections can be made that will keep the stars in their proper places. The perfection of the process really depends upon this delicacy of correction, which was not possible with the older methods, since these involved moving the whole telescope. How perfectly the astronomer can now work by expert manipulation of the adjusting screws, was shown by many wonderfully clear views with sharply-defined round star points, which at the same time were the result of hours of exposure. With such a method of setting the plate, the exposure may be continued over a number of nights, the plate holder

The "Owl" Nebula, Messier 97, in Ursa Major, photographed by Ritchey with the sixty-inch reflector, February 9, 1910. Exposure, 4 hours. One of the finest examples in the heavens of a "planetary" or "globular" nebula, with an exactly central star.



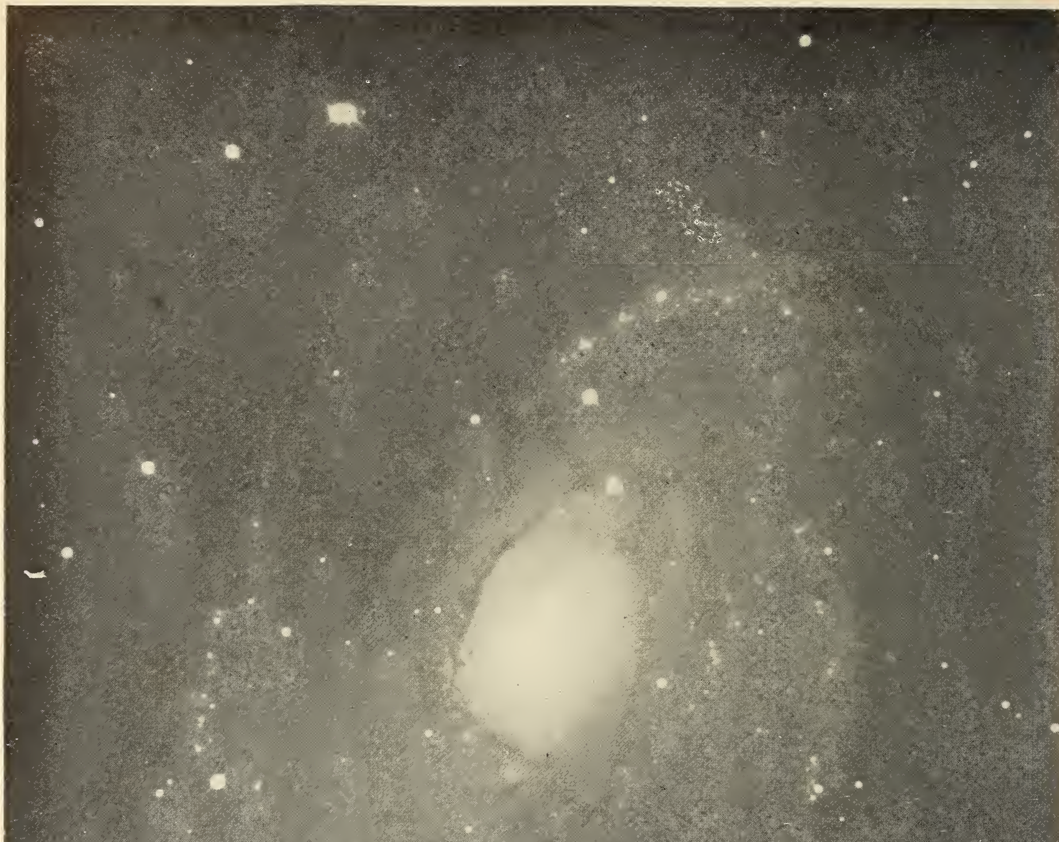
60-inch reflector mounting in dome

being taken out and kept in a light-proof place till some other favorable night gives the opportunity to expose it again.

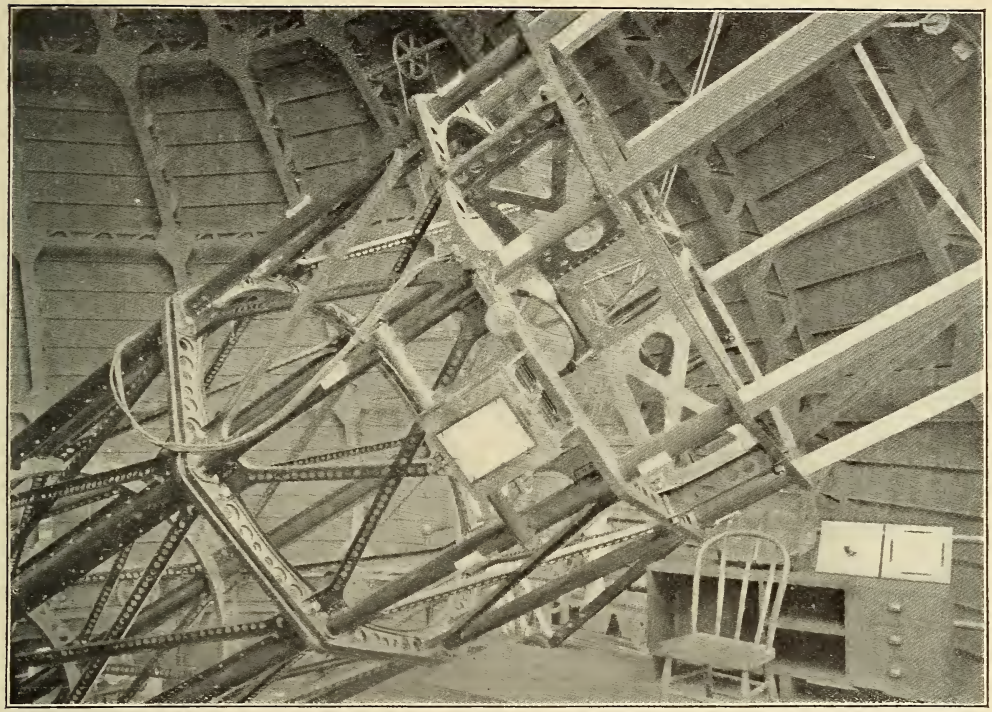
So well has the matter of removal and replacement of the plate-holder in the telescope been worked out that it is now customary to examine it and its attachments by taking them away from the telescope, perhaps a dozen times a night at Mt. Wilson, in order to see that there has been no change of conditions likely to affect the clearness of the images. In this work a test has been devised whereby the place of the focal plane of the images may be determined to within one thousandth of an inch.

The speaker then gave in detail the history of the different methods of keeping the stars always in the same spots on the plate. He noted the European custom of moving the telescope itself, and showed that it is obviously impossible to manipulate such enormous instruments as those at Lick or Yerkes in any such delicate way, since the corrections may need to be as numerous even as ten per second. The successful device, a plate-holder movable in two directions, was invented by Doctor Common, the English astronomer, but was never used by him. It has been perfected by Professor Ritchey, and is now the standard mechanism for delicate photography of the stars. It, of course, is to be understood, that when the conditions of the atmosphere are such that corrections of such delicacy cannot offset the inequalities of the air, it is useless to attempt photography.

The lecturer told very graphically the story of the struggle between the refractor and the reflector; the last of which, within the last fifteen years has come to supplant the former for the most delicate



Spiral Nebula, Messier 81, in the constellation of Ursa Major, photographed by Ritchey with the sixty-inch reflector, Mt. Wilson Observatory, February 5, 1910. Exposure, $4\frac{1}{4}$ hours. The dark rifts about the center of this nebula are remarkably like those in the Great Nebula in Andromeda. As in the case of all the spirals which Professor Ritchey has photographed with the sixty-inch, the convolutions of this nebula are shown to be condensing into soft nebulous stars; over 450 of these are to be counted in this photograph.



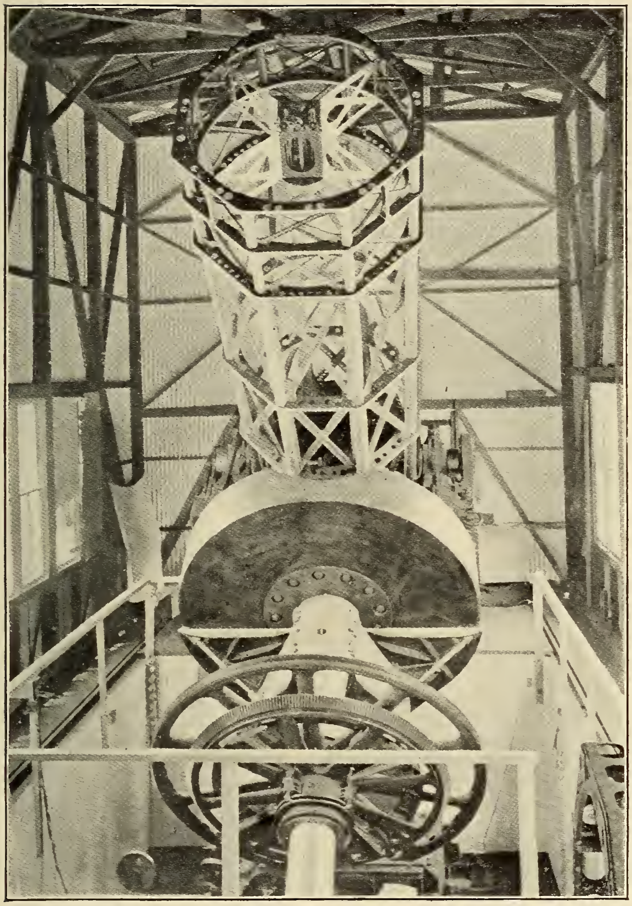
Double-slide plate carrier in principal focus of 60-inch reflector

photography. The reasons for this are that the mirror brings the illuminating rays and the chemical rays to the same focus, and needs no such correcting device as the refractor. In the second place, the enormous loss of light that large lenses entail is avoided to a very great extent when the mirror is used. In the refracting telescope of larger aperture the lenses absorb much light, since they are very thick, and they present also four surfaces, each of which is active in dispersing the light; so that the loss in the largest telescope of the day may be even as high as sixty per cent. of the amount striking the surface of the outer lens. It has long been evident that the limit of practicability is not very far away in the refracting telescope, beyond which it will be useless to increase it in aperture. This of course is assuming that no radical improvement is effected in the glass or its treatment. On the other hand, the loss of light in the reflecting form of telescope may be as high as ten per cent., in the smaller instruments, but does not increase at all as the mirror is made larger. Thanks to modern ingenuity the former disadvantages of the mirror have been removed, and even in the largest sizes it is well-nigh indispensable for photography.

Professor Ritchey for a while discussed the matter of sensitive plates, explaining to the company that the rays of different colors do not focus in precisely the same plane, and consequently the image from a mixed light is naturally confused. This led to the story of the orthochromatic screens, in which the speaker had done a remarkable work in the adaptation of them to special photographic researches in astrophysics.

Details of construction and methods of mounting occupied a considerable portion of the evening, leading very naturally to the difficulties of installation, which had particular reference to the establishment of the observatory on Mt. Wilson. The observatory was to be on the top of a

"Crab" Nebula, Messier 1, in the constellation of Taurus, photographed by Ritchey, with the sixty-inch reflector, October 13, 1909. Exposure, 3 hours. A very small nebula of most remarkable filamentous character, with hundreds of streamers resembling antennæ.



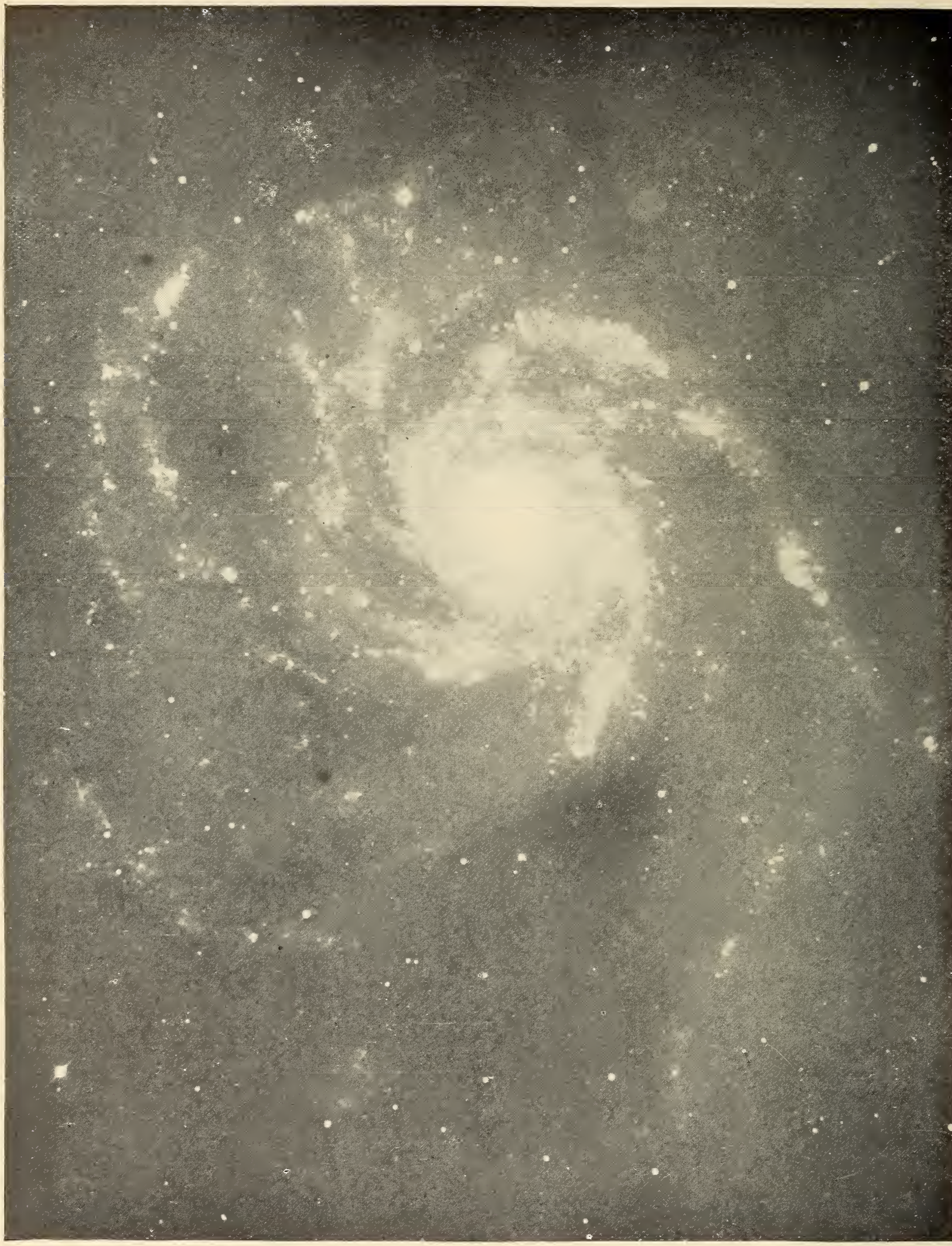
60-inch reflector mounting in erecting shop

two-foot telescope at the Yerkes observatory were shown, and others from institutions across the water. Some of Barnard's plates were exhibited, taken with a six-inch portrait lens, one of which by estimate contains fifty thousand stars. A pole star photograph was shown in which the camera was at rest, and the star trails were short arcs of circles. This picture gave evidence to the company, not only that the North star is not at the pole, but that there are about eighty-six small stars, readily to be photographed, between it and the pole. Most of the pictures, however, were of recent work with the 60-inch telescope on Mt. Wilson. Star clusters that even in a good-sized telescope are but glares of light were resolved into a myriad of independent, separate stars. The head of Halley's comet appeared a mass of what might be called "onion peel" envelopes, while the nebulæ were marvels of beauty. In explaining these views Professor Ritchey brought to notice the most recent bits of information. He showed the fuzzy stars that are part of the nebulæ, not observed in any previous work. They are quite different from the hard round stars with which everyone is quite familiar, and from their appearance and occasionally from rifts in the nebulæ in which they occur, are supposed to be unfinished stars, sweeping the regions through which they move clear of star dust.

The speaker showed many types of nebulæ, the splendid spirals of which there are tens or hundreds of thousands, believed to be systems like the solar system in course of evolution, and other nebulæ which may be even whole Milky Ways of stars, but at enormous distances. With

mountain in the wilderness, and it was necessary to build a road over which the transportation of heavy pieces of machinery could be possible, even with a grade of ten per cent. In this connection a description was given of the 60-horse-power motor wagon made especially for the purpose. A gasoline-engine-driven dynamo furnished the power which was divided between four motors, one on each wheel. The hind wheels had independent steering gear, so that no sharpness of turn was an obstacle, and every difficulty in the road was overcome by the independently moved wheels.

As to the lantern views, nothing like them has before been shown in Boston. For comparison, photographs with the



Messier 101, in the constellation of Ursa Major, photographed by Ritchey, March 10–11, 1910. Exposure, 7½ hours. One of the most perfect in form of all the spirals. More than 1,000 nebulous stars are shown in the convolutions, and many of these have accumulated into bunches of nebulous stars, connected by nebulosity.

the newer methods and the light gathering power that is possessed by the great modern telescopes it is now possible to note any changes. If the fuzzy nebula stars should move, the change of place could be determined, while in the nebulæ themselves, intersections in the wisps of light may now be identified and changes there would be seen and noted. Change of a whole nebula, however, is usually so slow as to be difficult of detection, and the speaker explained to his company how different portions of the processes as shown by different nebulæ in the sky could be put together to make a fairly complete story.

One of the most interesting pictures in the series was that containing sixty thousand stars (erroneously reported in the press as sixty thousand new systems) on seeing which Carnegie was impressed with the value of the work and gave another ten million to the institution which he had founded. At the same time the speaker noted that the 60-inch telescope now in place on Mt. Wilson is the gift of Mr. John D. Hooker of Los Angeles, who has made the offer to the observatory of the 100-inch telescope as soon as it can be constructed.

A good portion of the story of Professor Ritchey naturally related itself to the Mt. Wilson observatory, which is at the height of six thousand feet above sea level, not far from Pasadena, California. There is installed here a battery of instruments of which the 60-inch reflector is the king. This has a great many unusual features in its construction which were described; most remarkable among them being the mounting. This is by flotation in mercury. The telescope is housed in a dome of peculiar construction. It should be understood that with instruments of this kind it is necessary to keep them at a nearly even temperature. Optical glass changes its figure with heating or cooling, while annoying currents of air play about the aperture of the instrument when the observatory temperature differs from that outside. To maintain, as nearly as may be the temperature of the night throughout the day and thus afford the least possible range, the observatory is built with double sides and a metal roof, over which is a covering of canvas. The telescope is further protected by a special tent of blanket stuff. With all these devices changes in temperature are very nearly eliminated.

Professor Ritchey gave some insight into the plans for the 100-inch telescope, although the grinding of the mirror has not yet really begun. A disc of glass of nearly nine feet diameter and weighing more than a ton has been furnished by the French manufacturers, but it is doubtful whether it is sufficiently homogeneous. Some experiments are going forward to test this point, and if unsatisfactory another disc will be necessary. Meanwhile Professor Ritchey is himself experimenting to see whether a disc with cellular backing may not be built up which will give a lighter construction and avoid internal strain.

With the 100-inch reflector the intention is not to have a dome. The observers will work practically in the open with merely a wind shield about the instrument. There will thus be afforded the freest possible circulation of the outer air. For the protection of the telescope during the day, a house will of course be necessary, but at night this will be run by a motor along a railway track to a distance of seven or eight hundred feet from the instrument, sufficiently far so that its radiation of the heat gathered during the daytime can by no possibility affect the instrument. The intention is further to construct the house with walls of some insulating material, so that during the day, when it is protecting the telescope the temperature within the house shall be precisely that of the night before out of doors.

In recent forms of pocket cigar lighters, an alloy of iron and cerium is used to ignite the alcohol in the wick. This alloy has the interesting peculiarity of emitting bright sparks when struck by a hard piece of steel. The sparks give practically no heat, but will ignite combustible gases. The light emitted by the sparks is very brilliant and penetrating.

Trifid Nebula, Messier 20, in Sagittarius, photographed by Ritchey, June 4–5, 1910. Exposure, 3 hours, 26 minutes. A fine example of a "chaotic" nebula, probably a very early stage of development. It is especially remarkable for the sharply defined dark rifts and for the narrow, bright edges of the nebulosity in many places.

NEW LIGHT ON DESTRUCTION OF BACTERIA

RESEARCH IN THIS DIRECTION USING RADIATIONS FROM ELECTRICAL DISCHARGES — RESULTS OF INVESTIGATIONS IN STERILIZING WATER AND WITH LUPUS PATIENTS

One of the great problems which scientific men are at present called upon to solve is that of controlling the water supply of municipalities, so that it shall be rendered free from pathogenic bacteria before reaching the people for consumption. Given that the available supply for a town or city contains organisms which may be responsible for dysentery or typhoid fever; the people of that town or city naturally and rightfully demand the application of a simple, direct and economical method of sterilization. Many chemical methods, based on the addition of chlorine, ozone and other substances are in use, but there is always a strong popular prejudice against adding any chemical to drinking water. Recently attempts to sterilize water simply by exposure to ultra-violet rays have been made with considerable success.

Ultra-violet rays are invisible radiations of the same nature as visible light rays but of shorter wave-length. They are present in the radiant energy received from the sun, but most of them are absorbed by the atmosphere. Available sources of ultra-violet light are the various forms of electric discharge such as the arc, the mercury vapor lamp, and the spark. Glass is opaque to these radiations while quartz transmits them readily. Water, too, is fairly opaque, unless free from color and suspended matter, so that filtration is a necessary preliminary wherever this condition does not exist.

It has long been known that these ultra-violet radiations destroy bacteria subjected to their action, and all living cells are strongly affected by them. During the past three years a number of French investigators have been at work to make use of this fact to sterilize water on a large scale. A number of types of apparatus have been devised, the descriptions of which may be found in communications to the *Comptes Rendus de l'Academie des Sciences*. In an experimental run at Marseilles, water was flowed through a tank so as to pass over a quartz box containing a Westinghouse Cooper-Hewitt quartz mercury lamp, operating on 3 amperes and 220 volts. This operated successfully day and night for about six weeks, treating 600 cubic meters per 24 hours. During the test the raw water varied from 30 to 300 bacteria per cubic centimeter, with 50 to 1,000 colon bacilli per litre, indicating distinct pollution. After treatment no colon bacilli were ever found, and a potable water of the highest character was obtained. The energy consumption was 100 kilowatt-hours per million gallons and the cost $10 per million gallons. Very recently the cost has been reduced to $7.60 per million gallons, but even this is too costly according to American ideas.

Nevertheless the cost is not far out of range, and these experiments make it highly probable that, with some further improvement, this ideal method of sterilization will soon be made applicable to American conditions.

Direct therapeutic application of ultra-violet light in the treatment of lupus vulgaris and other grave superficial diseases has been made, chiefly by Finsen and his followers, in Europe. It is to be deplored that more is not being done in this direction on this continent. A dozen or so cases of lupus vulgaris have come under the writer's observation for which practically nothing was done by the medical fraternity. More in this connection in a subsequent paragraph.

These applications and the similar ones of sewage purification and milk sterilization, by utilization of radiant

energy of short wave-length, all depend for their improvement and practical success upon an understanding, or at least upon an empirical demonstration of the same fundamental facts. The author has been experimenting in this connection, with certain interruptions, during the past three years. A sufficient number of observations have been made to seem to warrant a preliminary statement being now given and the investigation is being extended so that more exact quantitative conclusions may be stated subsequently.

The Problems and Present Status

The experiments thus far seem to show that the radiation which is mostly effective in killing any particular bacteria which has been studied, is limited to a very narrow region of the ultra-violet spectrum, and that the most effective region differs in general with the specimen. The problems are, therefore, (1) to determine for any given bacteria, which wave-lengths are, for them, the most fatal, and (2) to arrange an electrical circuit containing resistance, inductance and capacity which shall be tuned so as to convert the energy supplied to a spark gap most efficiently into that particular region of the spectrum.

We must regard the first problem as being at present in a most unsatisfactory state, when we contemplate that at the Finsen Institute and at the various European hospitals which are at present utilizing the Finsen method, the radiations are simply those of an electric arc from which the heat rays are removed by water lens filters. Even this method has proved highly effective in helping lupus and kindred affections which usually prove fatal under other forms of treatment. Yet it seems probable, in view of the present investigation, that only a fraction of a per cent. of the radiant energy generated in this way is within the region of wave-lengths which are active, and that of those only a small fraction penetrates the water filter so as to reach the patient. For therapeutic application it would seem desirable to use a high potential spark discharge, rich in a certain region of ultra-violet radiation, rather than a low potential arc, rich in heat rays.

It has long been known that by simply introducing a suitable inductance in series with an electric arc, the air lines of its spectrum are eliminated, *i. e.*, the transformation of electrical energy into radiant light energy is markedly modified. This fact and related ones do not seem to be satisfactorily explained. Similarly the inductance, capacity, resistance and choice of material for electrodes may be varied in the case of the spark discharge, to throw more or less energy into a given region of the ultra-violet spectrum, and the second problem is that of effecting a choice of these for high efficiency. The matter of efficiency is of secondary importance so far as the problem has to do with therapeutic application, but it is of primary importance in connection with water sterilization and the other above mentioned applications.

Introductory Experiment. Apparatus

The writer was first directed to this investigation by being called upon to assist in the treatment of a case of lupus vulgaris. The case had failed to yield to any of the usual methods of treatment and the "Finsen Light" treatment was suggested by the physicians in charge. For reasons already given, the spark discharge seemed more desirable than the arc as a source of radiation, and in consequence the following circuit was arranged. A large induction coil, capable of giving a 30-inch spark, and operated from 110-volt mains by means of a motor-driven, Wehnelt interrupter, was placed in series with a variable inductance and a spark gap with iron electrodes. Across the spark gap was inserted a large variable capacity. The leads to this capacity were several feet of ordinary No. 14 copper wire. With a spark gap about one cm. long, the capacity was varied until a heavy, crackling, cold spark discharge was obtained, which was extremely rich in ultra-violet light. The patient was placed so that the radiation from the spark was concentrated over a

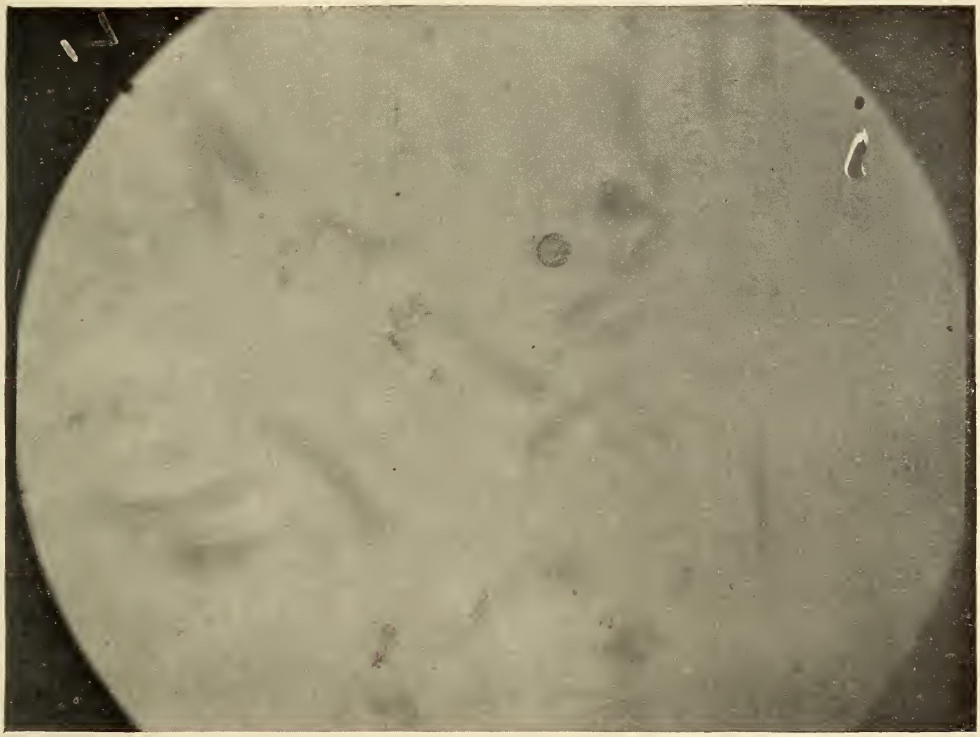


Plate I. Ameba myctotherus multisporiferous (dysentery) magnified 300 times. Exposure three seconds. Shows motion of organisms before raying. One individual is dead, or at least motionless

region about one inch in diameter by means of a quartz lens, and this area moved about until every part of the affected region had been rayed for one-half hour. From time to time changes in the circuit were made, and various metals tried as spark gap terminals. Such treatments were continued every second day or so for some weeks, and nothing particular noted, until one day cadmium terminals were tried and ribbons of copper wire used as leads to the condensers in shunt with the spark. At this the patient shrank back from the radiation, exclaiming that it felt as if thousands of needles were entering the open affected region. This result was not noticed if the leads to the condensers were of ordinary wire of considerable resistance, nor was it found with terminals of numerous metals except cadmium and alloys of cadmium.

Selective Radiation Inhibits Action of Yeast on Sugar

It was soon found that this same radiation, to which the patient was sensitive, inhibited the action of ordinary yeast cells upon sugar, which was judged by the generation of carbon-dioxide gas.

Whenever a mixture of yeast and sugar within a quartz vessel was rayed, the evolution of gas which accompanies the activity of the yeast cell was completely inhibited. If the mixture was in a glass tube the raying was ineffective. Hence, the effective radiation seems to be one for which quartz is transparent and glass opaque, that is, of the region of short wave lengths.

The arrangement of the circuit which was most effective in killing the yeast cells was also the most effective one for the patient. Any change in the arrangement of the electrical circuit varied the

effectiveness of the radiation emitted by the spark discharge, so far as its bacteriological effects were concerned.

Conclusion of Therapeutic Experiment

For subsequent applications of rays to the patient this yeast test was applied to ascertain whether the proper radiation was being emitted. During the earlier treatments the patient always felt the "pin and needle" sensation when the radiation was such that the yeast cells were inhibited and conversely. Later, with improvement, the patient experienced no sensation, so that some such control test as this was essential. This is not the place to discuss the therapeutic aspects of this phenomenon except in so far as they bear upon the general physical or physico-biological problem,

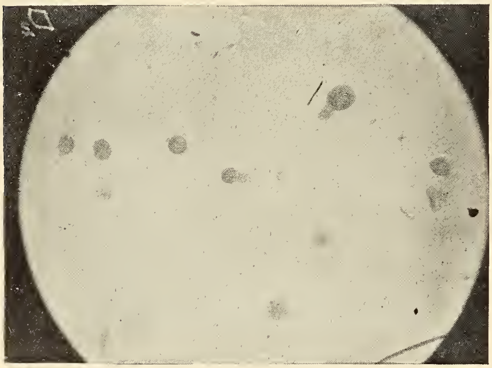


Plate II. same field as plate I. after raying for one minute. Organisms stationary; small perturbations visible

but it might be remarked in passing, that the raying treatment was continued every few days for six months, during which time the affected region shrank from an area of about five square inches to nothing, and that no ill effects have since been experienced after a lapse of two years. Several other cases of lupus vulgaris were rayed in this manner, and in every case an improvement was noticed after very few treatments.

Selective Radiation and Bacteria

Meanwhile, certain cultures of bacteria most of which were furnished and tested by Doctor Walker of the Harvard Medical School, to whom the writer is greatly indebted for his generosity and interest, were studied under the influence of these radiations. Some arrangement of the circuit could always be found to effectively kill each specimen studied, but the best arrangement varied greatly from one bacteria to another. For example, ten seconds' raying with cadmium terminals and ribbon leads served to completely kill a culture of tubercle bacillus, while prolonged raying with iron terminals in place of cadmium, or with ordinary leads as not fatal to them, while *ameba myctotherus multisporiferus* or *entameba hystolytica* (dysentery), which is very many times larger, and which is much less sensitive to changes of temperature, etc., are killed with thirty seconds' raying with any one of about twenty different arrangements of the circuit tried.

It seems, therefore, likely that the radiation absorbed by a given bacterium and which is fatal to its vital processes, is a selected one of a very limited range of wave-length. Consequently, one might expect to be able to spread a culture, which gave some characteristic stain, uniformly over a plate, and by dispersing the radiant energy either with a quartz prism, or with a grating to obtain a bacteriograph, marking the effective radiations.

Observations Under the Microscope

Direct observations were made of the effect of various wave-lengths of radiation upon the following bacteria and ameba: B *coli communis*, A *myctotherus multisporiferus* (dysentery), *trypanoplasma* (sleeping sickness), and *mastigina* or *mastigamcba*, which are sufficiently varied and typical, by noting their motion under the microscope during the raying process. In each case some arrangement of the circuit proved effective, and when once found it could be reproduced at will, with uniform results. The results are given in a later paragraph.

However, so arbitrary did the effectiveness seem to be in terms of the constants of the circuit or of the apparent properties of the radiation that no general deductions have as yet been made. Photographs of the ultra-violet spectral lines

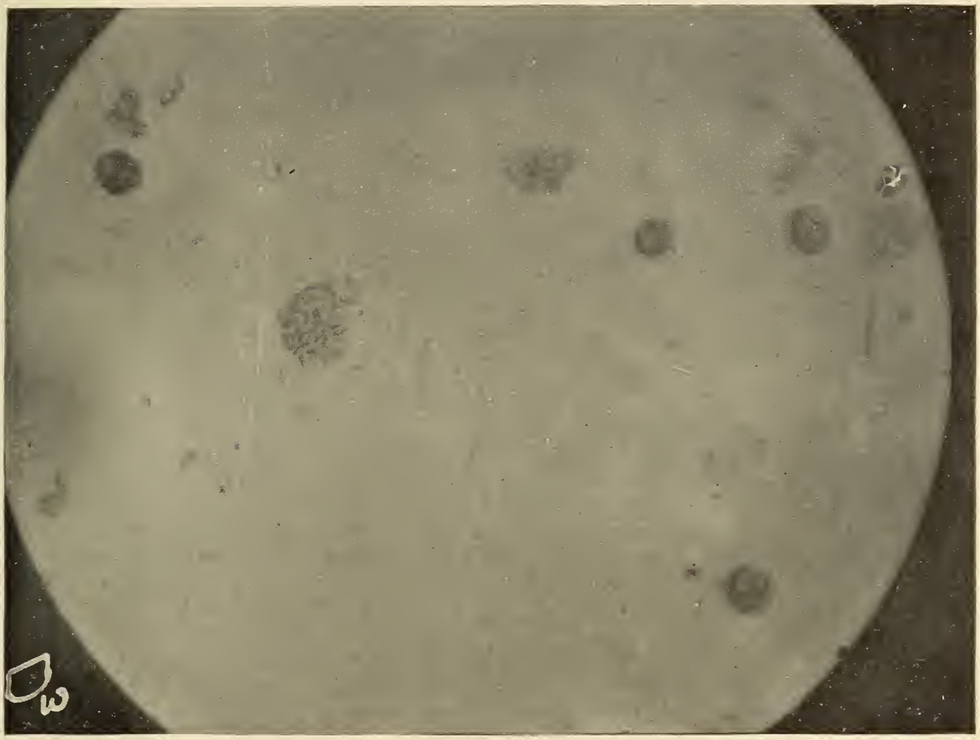


Plate III. Same field as plates I. and II., after raying three minutes. Loose irregular structure superseding firm spherical form

were often times identical as near as could be seen for two arrangements of the circuit, and yet a tremendous variation in the effectiveness of the radiation was noted. At times the writer was led to believe that the effective radiation must be other than that commonly supposed to be emitted from such a spark discharge. This possibility seems well worth investigating and it is hoped that this preliminary report may interest others to do so.

Secondary Effects

The action may, of course, be due to some unsuspected secondary effect, and experiments are in preparation to test this more thoroughly. It was immediately suspected that the cause might be the chemical effect of the ozone generated in the air by the spark, but in this case it would be difficult to see why the effect should be inhibited by placing the specimen within a glass tube, which is open to the air at the top, and not in a similar open quartz tube. This does not preclude the possibility of the reaction to form ozone taking place at the expense of the air which is dissolved in the water. This possibility needs to be further studied. If found to be true it might greatly modify the procedure at present adopted for water supply sterilization.

Penetrability of Radiation

It seems surprising that the effect is so complete, resulting in the total destruction of the bacteria or cell with a few minutes raying, throughout the entire volume of the liquid. In many experiments this meant that the radiation must have penetrated nearly a centimeter of strong solution, and there is much evidence in the literature that such a thickness is opaque to ordinary ultra-violet light. It was soon found that the radiation restored the color to a fuchsine solution which had been decolorized with

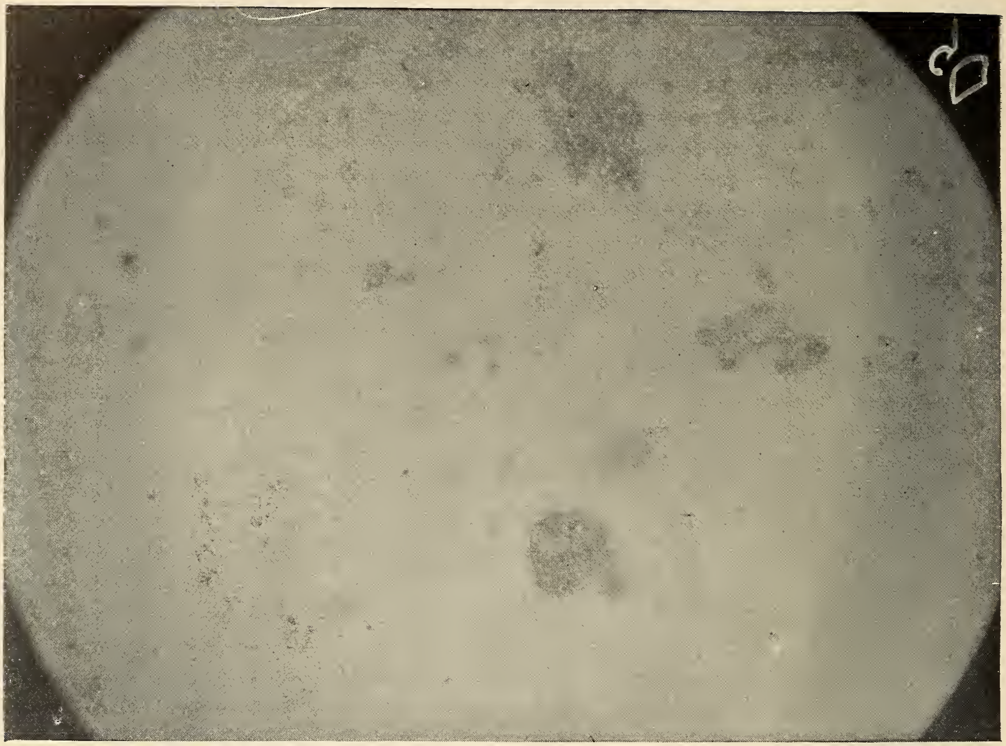


Plate IV. Same as plates I., II. and III., after raying five minutes. Almost complete disintegration

sulphurous acid. Moreover, this return of color seemed to be uniform throughout the volume of the solution when enclosed in a quartz tube and rayed, and was not observed when the solution was shielded by glass.

Direct Observations and Results

The following method was adopted to observe directly the effect of the radiation upon a culture. A sample was placed between quartz microscope slides, and a control sample similarly placed between glass ones. This second sample was treated throughout, like the first one, and served as a control. In almost every case after an experiment the bacteria protected by the glass were found to be active, and a failure to find this was of course sufficient cause to discard that observation. The quartz sample was placed on the mount of a microscope and the instrument focused with a projection eye piece so as to bring a sharp image of the active bacteria on a ground glass plate of a camera arranged vertically above the microscope axis. The operations were performed in a dark room, and a beam of light from a lantern, after being passed through a water filter, served to illuminate the field of view. In this manner a field containing perhaps a dozen active individual organisms could be observed on the ground glass, magnified in many cases, so that each individual was several millimeters in diameter, and so that the motion was a centimeter or more in a few seconds. The spark was placed so as to ray the specimen, and the character of the effect watched. When an adjustment of the electrical circuit was found which rendered the raying effective at all, the results were uniformly as follows: The beam of light used for illumination served to excite the organism to great activity, but in no case under observation did it tend to decrease the activity however long produced, up to the time the culture started to dry out. Hence, before raying, each individual of

the culture was seen to be moving with various speeds and along various curves. This is shown in plate I., which is a photograph of *ameba myctotherus multisporiferus* taken by replacing the ground glass by a photographic plate. The exposure was for three seconds, so that the extent of the motion may be judged. The magnification is about 300 diameters. One individual is seen to be dead, or at any rate motionless. Naturally the paths thus shown would be faint, for each portion of the path was shadowed by the ameba as it moved onward during the three seconds of exposure for only a fraction of that time. The circuit was then closed and the culture rayed for various lengths of time. The activity of the specimen for the first few seconds was increased to the point of apparent frenzy, after which each individual assumed an approximately spherical shape, and remained motionless. Plate II. is a photograph of the same field as plate I, taken after raying for one minute. This and each subsequent picture was given a three-second exposure. With further raying the firm spherical appearance yields and a loose irregular structure supersedes it. This is shown in plate III. which is after raying three minutes. Often during early stages of the raying perturbations break out, as if the individual had burst. This is clearly shown in plate II. With further raying disintegration takes place, and finally the subdivisions become so small as to be lost to view. The early stages of this are shown in plate IV., which is the same field as the earlier plates (I., II. and III.) after five minutes raying. Of course all the pictures were taken with the same magnification.

It would, therefore, seem that the direction in which one might look for improvement in applying this radiant energy to water sterilization and other processes would be that of a more carefully tuned electrical circuit. The present methods are very much as if we should attempt to heat our rooms with incandescent lamps. To be sure they do radiate heat and enough of them would suffice, but why have such an extravagant burst of light energy if it is heat that is desired. To kill the bacteria which are offensive in drinking water a very limited region of wave-lengths of radiant energy is effective. All other wave-lengths are wasted and, of course, lower the efficiency and increase the cost. This research is to be continued to attempt to map the effective wave-lengths and to devise a method to produce them efficiently.

The experiments in connection with this paper were performed at the physical laboratory of the Massachusetts Institute of Technology at Boston.

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H. T. Kalmus.

REAL AND FANCIED SOURCES OF DISEASE*

SCIENCE IS DRAWING THE LINE BETWEEN PUBLIC HEALTH MEASURES OF PROVED VALUE AND THOSE THAT OWE THEIR EXISTENCE TO TRADITION

Public health experts today agree in looking upon certain practical measures as of unquestionable value in conserving the health of a community, while they regard others as relatively ineffective or even worthless. It is true, however, that, in spite of the existence of definite principles and well-established facts a part of the activity of almost every municipal health department in this country is devoted to combating imaginary dangers or applied to tasks that have only a remote bearing on the public health.

This condition as a rule is not due either to apathy or ignorance on the part of health officials, but to the pressure of public opinion. Such pressure is often exerted directly through legal ordinances passed by uninformed legislative bodies but sometimes also through agitation by mistaken enthusiasts or through other channels of public opinion. Back of the whole situation is the survival in the public mind of antiquated conceptions of disease and causes of disease. It has been unfortunate in many respects for the cause of public health that much of the popular interest in health matters was evoked before the germ theory of disease and its corollaries became fully developed. This resulted in fixing in the public mind a number of wrong conceptions of disease and of combating disease which has become traditional.

To be specific, two instances of this confusion are found in the demand for garbage disposal and plumbing inspection. Sanitarians do not admit that even a grossly improper method of garbage disposal can have much to do with the spread of disease in a large city or that diphtheria or typhoid fever or any other disease is properly attributable to the entrance of sewer air into dwelling houses. So firmly embedded in public belief, however, is the connection of piles of decaying garbage with outbreaks of infectious disease, and of "defective plumbing" with all sorts of maladies that to the average citizen "garbage disposal" and "plumbing inspection" bulk large as the chief if not the only activities of a municipal health department.

In the light of our present knowledge we may well ask what are actually the known dangers to health from these two sources? It is now well known to bacteriologists that disease germs do not "breed" in garbage heaps, but that on the contrary if added from outside they speedily die off. The offensive odors of decomposition may be unpleasant and undesirable; there is no evidence that they produce disease or dispose to disease. On the other hand, it is true that the existence of heaps of decomposing organic matter may tend to maintain or create general habits of uncleanliness which themselves may be detrimental in a roundabout way to the health of a community. And again it is known that the house-fly may breed in garbage piles, particularly if horse manure is present, and that under certain conditions this noxious insect may become the bearer of disease germs to food. But when the worst is said it must be admitted that the actual danger to health from garbage piles and "dumps" is relatively insignificant compared with the danger from other well-known but less popularly feared sources. Disease does not originate in garbage piles, however offensive they may

*By Edwin O. Jordan, Professor of Bacteriology, University of Chicago, presented before the Congress of Technology at the Fiftieth Anniversary of the Granting of the Charter of the Massachusetts Institute of Technology.

be: the house-fly, however disgusting and annoying its habits, does not carry disease germs unless it has access to material in which they are present. The truth is that garbage disposal is more a matter of municipal housekeeping than of public health; a proper method of garbage collection and destruction is desirable rather from economic and esthetic considerations than on hygienic grounds. There are of course certain features in the handling of refuse and waste that need hygienic control, just as there are in street cleaning, but the problem is essentially not one of public health. At present in some cities the department of health is burdened with the task of caring for the city waste and its success or failure as a conservator of public health is too often measured by the frequency with which coal ashes are scattered in alleys or the length of time that decaying vegetable matter remains in tin cans in hot weather. In some cases the larger part of the annual health department appropriation must be expended for garbage collection and disposal, leaving only a pitifully small residue for other needs. To mention a single instance, the collection and conservation of garbage and ashes cost the Minneapolis Health Department in 1909 about $57,000, leaving approximately $43,000 for all other activities of the department. This latter sum is about one fifth of the amount expended for these other activities by the city of Boston for a population approximately twice that of Minneapolis.

One thing should be clearly understood by municipal authorities and by the general public, that regular collection and cleanly handling of ashes and table scraps is not one of the surest and most profitable ways of protecting health and preventing disease. Efficient administration of this branch of public work should not be allowed to take the place of more directly fruitful measures.

Few dangers to health have loomed larger in the public eye than that from "sewer gas." Elaborate and amazingly expensive systems of plumbing are required by law to be installed in every newly erected dwelling house in our large American cities. Plumbing inspection today occupies a large part of the working force of many municipal health departments. In Baltimore, in 1908, to cite a single instance, this work was carried out by one inspector of plumbing, seven assistant inspectors of plumbing and one drain inspector at a total salary cost of $8,250 or about one tenth of the total salary appropriation for all public health work. And yet, if the most recent and searching investigation such as those of Winslow and others are to be believed, the actual peril to health involved in the entrance of small quantities of sewer air into houses is so small as to be practically negligible. It may be questioned whether plumbing inspection, as ordinarily conducted, can be shown to save a single life or prevent a single case of disease. There is certainly no reason to suppose that any infectious disease is due to germs carried in sewer air. It might reasonably be maintained that slightly leaky gas fixtures are a much more serious menace to the health of house dwellers than defective plumbing. At all events our present knowledge affords small justification for the expenditure of public money to insure that the odor of peppermint does not enter our houses when oil of peppermint is designedly introduced into the house drains. It may be worth while for the homebuilder to satisfy himself of the character of the plumbing as of the character of the mortar, but compulsory inspection by public officials is hardly warranted on the ground of high degree of demonstrated danger to the public health. It is certain, too, that the enforced installation of immensely complicated and elaborate piping and trapping systems simply adds to the cost of living without any compensating hygienic advantages. The plumbing ordinances of our large cities often contain inconsistences and contradictions, what is required in one city being sometimes forbidden in another. A revision and simplification of municipal plumbing regulations, a minimizing of official inspection and especially an education of the

public to the fact that diphtheria, typhoid fever and scarlet fever have never been definitely traced to sewer air or bad plumbing are means that might release a considerable sum of public money for use in profitable lines of sanitary endeavor.

Another function at present required of or voluntarily exercised by health departments is the practice of terminal disinfection after cases of infectious disease. This has come to play a large part in municipal health activities and is responsible for an important share of the expense. In Boston, for example, in 1909 about one tenth of the annual appropriation was expended for disinfection. One of the most experienced New England city health officers has recently seriously questioned the value of such an expenditure for this purpose (Chapin, "Journal American Public Health Association," 1911, 1, p. 32). After a study of the ratios of recurrences in certain diseases he concludes that "Both theory and facts, so far as any data are available, indicate that terminal disinfection after diphtheria and scarlet fever is of no appreciable value." This view has met with strong support. It is evident that the whole question of disinfection needs to be studied afresh with a view to actual efficacy. It is not a subject for laboratory experimentation alone, but must be investigated as a problem of practical public health administration.

Other instances of the application of energy and money to measures apparently of slight or doubtful value might be cited, but those already given are fairly typical. The question in all cases is not whether a particular measure is entirely devoid of value, but whether it is the most effective way of utilizing available resources.

As a matter of fact there are a number of unquestionably valuable measures that cannot be prosecuted with sufficient vigor because of the enforced diversion of funds into other and less profitable channels. Profitable measures may sometimes be distinguished from the fruitless or relatively unprofitable by their direct and unmistakable outcome in the saving of life and the prevention of disease. A few illustrations may be noted. The importance of control and the supervision of the sources of public water supply has long been recognized, but the importance of controlling the quality of the public milk supply, although frequently urged by sanitarians, is not always appreciated. At the present time in the great majority of American cities it is safe to say that for every case of infectious disease due to drinking water ten cases are caused by infected milk. It is difficult to secure adequate funds for the sanitary control of the milk supply. By sanitary control of milk is meant not the upholding of a rigorous standard of butter-fat and total solids, but the maintenance of proper standards of cleanliness and health for dairy cows and especially the safeguarding of the milk from infection during collection and transportation. Under some conditions the protection of the consumer against milk-borne infection may be best brought about by compulsory pasteurization of that portion of the milk supply which cannot otherwise be raised to proper standard. Whatever method of control be adopted, it is certain that any genuine improvement in the character of a milk supply will meet with a response, in a lessening in the amount of typhoid fever, diphtheria, scarlet fever and to some extent tuberculosis. The early detection of a single case of typhoid fever or scarlet fever on a dairy farm may be the means not only of preventing an extensive epidemic, but of avoiding the formation of scores of new foci which can in time serve to light up subsequent cases for many years. Proper pasteurization of milk has been followed in many cities, as in Glasgow, Liverpool and London, by an immediate and material reduction in the amount of typhoid fever. In other words the connection between an expenditure of public money and a direct return in prevention of disease can be more clearly demonstrated in the case of milk-supply control than in some other of the usual municipal health department activities.

The question whether the quality of a city milk supply can be more favorably influenced by inspection and supervision

at the source or by generally enforced and controlled pasteurization is one upon which there is still some difference of opinion among experts. There is little doubt, however, that simply as a matter of economy of administration much is to be said at present in favor of centralized pasteurization of a large portion of the supply. Viewed as a method for preventing a large number of cases of infectious disease at relatively small expenditure the pasteurization of milk certainly ranks high among effective health measures.

One of the important bacteriological advances of the last few years has been the discovery that a considerable number of healthy persons, convalescents or others, harbor disease germs and that these persons are important agents in spreading disease. The detection and proper treatment of disease germ-carriers, particularly in the more serious diseases and before or in the early stages of an epidemic, is now recognized as an important although difficult task. From this point of view inspection of school children especially at the beginning of the school year, is probably to be classed as a highly profitable activity, although it is to be wished that fuller and better-studied statistics were available. The whole question of the control of germ-carriers is one that needs more careful study with a view to determining the actual results of the methods employed.

As an undoubtedly important protective measure is to be put the adoption of a safeguarded and standardized form of privy in all rural communities and the total abolition of the privy in all thickly settled towns. For lack of such regulations soil pollution occurs, the house-fly finds an opportunity to transfer disease germs and typhoid fever and hookworm disease become constant plagues over wide regions.

In the campaign against tuberculosis, it is perhaps too early to evaluate the numerous methods that have been proposed for lessening or eradicating this disease, but it is already evident that some are more directly repaying than others in proportion to the effort involved. Among the methods for which public funds are legitimately available none is more promising than the provision of sanatoria for advanced cases of consumption. Newsholme and Koch have shown that the general diminution in the death rate from tuberculosis observed in most countries can be more readily traced to this source than to any other, and that in addition to its humanitarian advantages of segregation and proper control of the advanced and dangerously infective cases is one of the most useful methods that can be employed by the community to protect itself against the spread of tuberculous infection.

Another field in which practical workers are convinced that certain measures have direct efficacy in saving life is that of infant mortality. It has even been said that for the expenditure of a certain sum the saving of a life can be guaranteed. Certain it is that in few public health activities is ratio between effort expended and results obtained so clearly seen. No one doubts today that prompt notification of births, education of the mother through any one of a number of agencies and special provision for suitable feeding of infants during hot weather are factors that are bound to tell powerfully in the reduction of infant mortality. It may confidently be asserted that the degree of success achieved will be limited only by the amount of endeavor the community is willing to put forth. In the prevention of infant mortality public health activity need not be directed toward remote or possible dangers, but to removing or remedying causes known to produce loss of life.

It is impossible at present to apply direct tests of efficiency to some measures that undoubtedly promote health. The influence of playgrounds, public baths, regulation of the hours of labor in extra arduous industries and the like is real if it cannot be accurately determined or estimated. Certain activities of a health department may be worth continuing for their educational value, although their direct utility may be questioned. Many topics need investigation in order to discover their real bearing upon the

public health, such as the effect of a smoky atmosphere, the alleged nervous strain due to city noise and numerous questions in the domain of food adulteration and contamination. Premature and drastic action by health authorities in matters concerning which there is profound disagreement among experts may cast discredit on other lines of activity in which there is and can be no difference of opinion.

For the present it seems worth while to emphasize more sharply than heretofore the distinction between public health measures of proved value and those that owe their existence to tradition or to misdirected and premature enthusiasm. Further study of the actual effect of particular activities is also much needed and as a preliminary to such study the proper collection and handling of vital statistics is essential. It is poor management and unscientific procedure to continue to work blindly in mattters pertaining to the public health, to employ measures of whose real efficiency we are ignorant and even to refrain from collecting facts that might throw light upon their efficiency.

WHOLESOMENESS OF ICE

Professor Sedgwick in charge of the Department of Biology and Public Health has been devoting a great deal of attention to the subject of the wholesomeness of ice. He made the following statement before a convention of ice dealers which is having wide circulation in the daily press:

"Many typhoid germs are killed by freezing and after two weeks' exposure in the ice, upwards of 99 per cent. die, the remaining germs, while quite hardy, gradually are weakened and eventually die. As a vehicle of disease, ice is plainly far less dangerous to the public health than is either water or milk."

Professor Sedgwick further stated, "I consider that this statement should be a most valuable one. The public most certainly has an idea that ice is more dangerous than either water or milk and it is your duty that this idea should be permanently removed from their minds.

"In my tests I have shown that typhoid bacilli are killed when stored in ice after nine weeks, and that B. Coli Communis, the ordinary intestinal germs, are killed after a period of twelve weeks. Most natural ice is stored for longer than this period and while you are aware of these facts, the public to whom you sell the ice is not aware of them. I have made a large number of examinations this winter and for the past five or six winters, of ice harvested in New York, Pennsylvania, New Jersey and Connecticut, and in every case where a subsequent examination was made in June or July the accuracy of my figures as to the effect of temperature on bacteria in ice, has been verified."

THE POWER OF AN AIR BRAKE

Some idea of the power of an air-brake may be gained from the following facts: It takes a powerful locomotive drawing a train of ten passenger cars a distance of about five miles to reach a speed of sixty miles per hour on a straight and level track. The brakes will stop the same train from a speed of sixty miles per hour in 700 feet. Roughly it may be stated that a train may be stopped by the brakes in about three per cent. of the distance that must be covered to give it its speed.
L. E. M.

GAS ENGINES IN HIGH ALTITUDES

A large gas engine plant was recently erected several thousand feet above sea level. The engines did not give the power expected, and it was finally concluded that the loss was due to the altitude of the station. Upon investigation of the theoretical and practical considerations involved, it was found that there is a loss of about one per cent. of the indicated horse power for each 1,000 feet of increase in elevation. The effect with a low ratio of compression, is slightly less than with a high degree of compression.

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The Aim of Science Conspectus

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In enlarging the scope of the publication of the Society of Arts it is our aim to give, as far as we may be able, a general survey of the field of science and its applications in such a way that every article will have some educational value for every reader. We shall strive to describe the most important current developments in the field of scientific activity in terms within the understanding of the intelligent lay reader, and in general we shall confine these descriptions to reasonable limits, often to the extent of brevity. We shall not attempt to preserve a balance in the amount of material presented between various branches of science. Most of the articles will be original material from authorities in their special lines of investigation. The publication staff will, however, make digests and summaries of important articles as they may appear in current publications, and we shall not hesitate to reprint any articles which may be of particular value to our readers. The matter in SCIENCE CONSPECTUS will not be printed simply because it is available, but will be carefully selected, and wherever possible will be amply illustrated.

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